BBC

SPECIAL REPORT: SATELLITE CONSTELLATIONS

Starlink's impact for pro & amateur astronomers

#181 JUNE 2020

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

STARGAZING SPECIAL

SUMMER SKIES

Discover spectacular sights in the season of short nights:

- Noctilucent clouds
- See the planets in daylight
- Sun dogs, solar halos and more

VENUS MEETS THE MOON

And more essential observing this month

HIMALAYAN RING OF FIRE

How this month's solar eclipse at the roof of the world is unique

DARK ADAPTED

Canon's new astro imaging camera on test

CRATER COUNTING

Why the way we date planets is due a review

SEARCH IN THE DARK

The hunt for missing mid-size black holes

ISOLATED ON ICE

How Antarctic scientists deal with social distancing

Sky-Watcher®

Be amazed.

POPULAR BEGINNER & INTERMEDIATE NEWTONIAN REFLECTORS

Sky at Night MAGAZINE GROUP TEST WINNER

ASTROLUX
76mm f/9.2 REFLECTOR

SRP £89.99

Sky at Night MAGAZINE GROUP TEST WINNER

SRP £165

"The optics were so good…. the review instrument certainly delivered in every important respect"
BBC SKY AT NIGHT MAGAZINE

SKYHAWK-1145P (EQ1)
114mm f/4.4 PARABOLIC REFLECTOR

SRP £195

"This telescope made observing the night sky enjoyable….great views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-130 (EQ2)
130mm f/6.92 REFLECTOR

EXPLORER-150P (EQ3-2)
150mm f/5 PARABOLIC REFLECTOR

"Good for advanced observing… Saturn was a stunning sight"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE HIGHLY COMMENDED 87%

SRP £389

EXPLORER-150PL (EQ3-2)
150mm f/8 PARABOLIC REFLECTOR

SRP £389

EXPLORER-200P (EQ5)
200mm f/5 PARABOLIC REFLECTOR

"Passed all our tests with flying colours and was a delight to use both optically and mechanically"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE GROUP TEST WINNER

SRP £585

SKYLINER-150P CLASSIC
153mm f/7.8 PARABOLIC DOBSONIAN

SRP £259

SRP £349

Sky at Night MAGAZINE HIGHLY COMMENDED 93%

"Turning to Saturn, the view really took our breath away….The Skyliner was a joke to use"
BBC SKY AT NIGHT MAGAZINE

SKYLINER-200P CLASSIC
203mm f/5.9 PARABOLIC DOBSONIAN

SKYLINER-250P CLASSIC
254mm f/4.7 PARABOLIC DOBSONIAN

SRP £519

INFINITY-76P CHILDREN'S
76mm f/4 PARABOLIC REFLECTOR

SRP £52.99

SRP £62.99

Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 111 August 2014

SRP £115

HERITAGE-100P
100mm f/4 PARABOLIC DOBSONIAN

SRP £179

HERITAGE-76
76mm f/4 DOBSONIAN

HERITAGE-130P FLEXTUBE™
130mm f/5 PARABOLIC DOBSONIAN

Email for 88 Page **FREE** Catalogue

OVL

Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk

YOUR SMARTPHONE AND YOUR TELESCOPE WILL NOW BE THE BEST OF FRIENDS

Push+ Go object finder for Dobsonian telescopes

omegon®

Push+ GO!

Smartphone holder: for all smartphones up to 3 inch (75mm) wide

Exploring the sky will become a completely new experience. You will be able to find every planet and deep-sky object! The new Push+ Go system makes all this possible: with digital encoders together with your Android smartphone. As soon as you have downloaded the SkySafari® app you're ready to go. On the display you will see a digital star chart and the direction in which your telescope is currently pointing. In this way you will find every object and get to know the sky at the same time.

Easy to retrofit

Transform your Dobsonian telescope into a unique object-finder system. All the components you need are already included. You can install the set in a few simple steps, it'll take just 10-15 minutes. Suitable for many common Dobsonian telescopes:
- Omegon Dobson Advanced X N 203/1200, 254/1250, 304/1500
- GSO Optical Classic 8", 10", 12"
- Orion® SkyQuest XT4.5, XT8, XT10, XT12 Classic Dobson
- TS Dobsons Classic Line
- ICS Galaxy Dobson

BLUETOOTH™

Easy to operate: BLUETOOTH™ 2.0 enables a wireless connection to your smartphone. Simply insert your phone into the holder and say goodbye to cable chaos. Range of up to 33 feet (10m)!

Digital Encoders

Your telescope immediately knows where it is. The technology used by the large equatorial mounts can now also be found in the Push+ Go. Thanks to two precise digital encoders you can follow every step and find objects in an instant.

Software

Use the SkySafari® 4 Plus (or later) app for Android to control your telescope. From now on, locating objects in your telescope will be the easiest of tasks.

Power bank included

You don't need to worry about a power source since a power bank is already included. Simply plug in the cable and get going. You have enough power for the entire night.

£192

Product nr. 55768

Android™ required

Bluetooth® 2.0 required

Welcome

Get ready to enjoy the skies in the summer season

As the editorial team puts the finishing touches to our second issue produced during lockdown, I hope you are finding ways to cope with the changes to everyday life. For me the night sky has been a source of solace during this time, reassuring in its permanence and fascinating in its detail.

As we move into summer and dark nights depart for the season, the good news is that this consolation does not disappear – and this issue we're showing that it's still possible to study the sky. On page 26, Stuart Atkinson introduces us to noctilucent clouds, those bewitching iridescent displays at the very edge of our atmosphere. Their appearance provides drama to twilight northerly horizons from this month throughout the summer, but can often pass overlooked; be sure to know what to spot.

There are many more targets to see, and Paul Money guides you to them in his feature on daylight astronomy, starting on page 56. If you've not tried spotting the planets or the brighter stars against a cerulean sky, make this the summer you start!

To enable you to get the latest observing tips and tricks while the usual outlets you pick your issues up from remain closed, we've extended our special subscription offer. You can have your next three issues delivered to your home, without starting a Direct Debit, while still saving on the shop price. If you're happy to set up a Direct Debit you'll make even more savings, and your first six issues will be just £9.99. Pick what works for you by visiting **www.buysubscriptions.com/SKspring3** or call us on **03330 162 119** and quote code 'SPR3MPG, *BBC Sky at Night Magazine*'. See page 76 for more.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 18 June.

HOW TO CONTACT US

Subscriptions, binders and back issues
03330 162119*
Mon–Fri 8am–6pm; Sat 9am–1pm

*Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. If calling from overseas, please dial +44 (0)1604 973727

Editorial enquiries
+44 (0)117 300 8754
9.30am–5.30pm, Mon–Fri

Advertising enquiries
+44 (0)117 300 8145

Print subscription enquiries
bbcskyatnight@buysubscriptions.com

Digital subscription enquiries
bbcskyatnightdigital@buysubscriptions.com

Editorial enquiries
contactus@skyatnightmagazine.com

Subscription enquiries
UK enquiries: FREEPOST IMMEDIATE MEDIA (please write in capitals)
Overseas enquiries: PO Box 3320, 3 Queensbridge, Northampton NN4 7BF, UK

Editorial enquiries
BBC Sky at Night Magazine, Immediate Media Co Bristol Ltd, Eagle House, Colston Avenue, Bristol BS1 4ST

Become an Insider

The more we know about what you like, the better placed we are to bring you the best magazine possible. So we'd like to invite you to join our online reader panel 'Insiders'. Just log on to **www.immediateinsiders.com/register** to fill out the short registration survey and we'll be in touch from time to time to ask for your opinions on the magazine and other relevant issues.

CONTENTS

C = on the cover

Features

Regulars

Astrophotography

Reviews

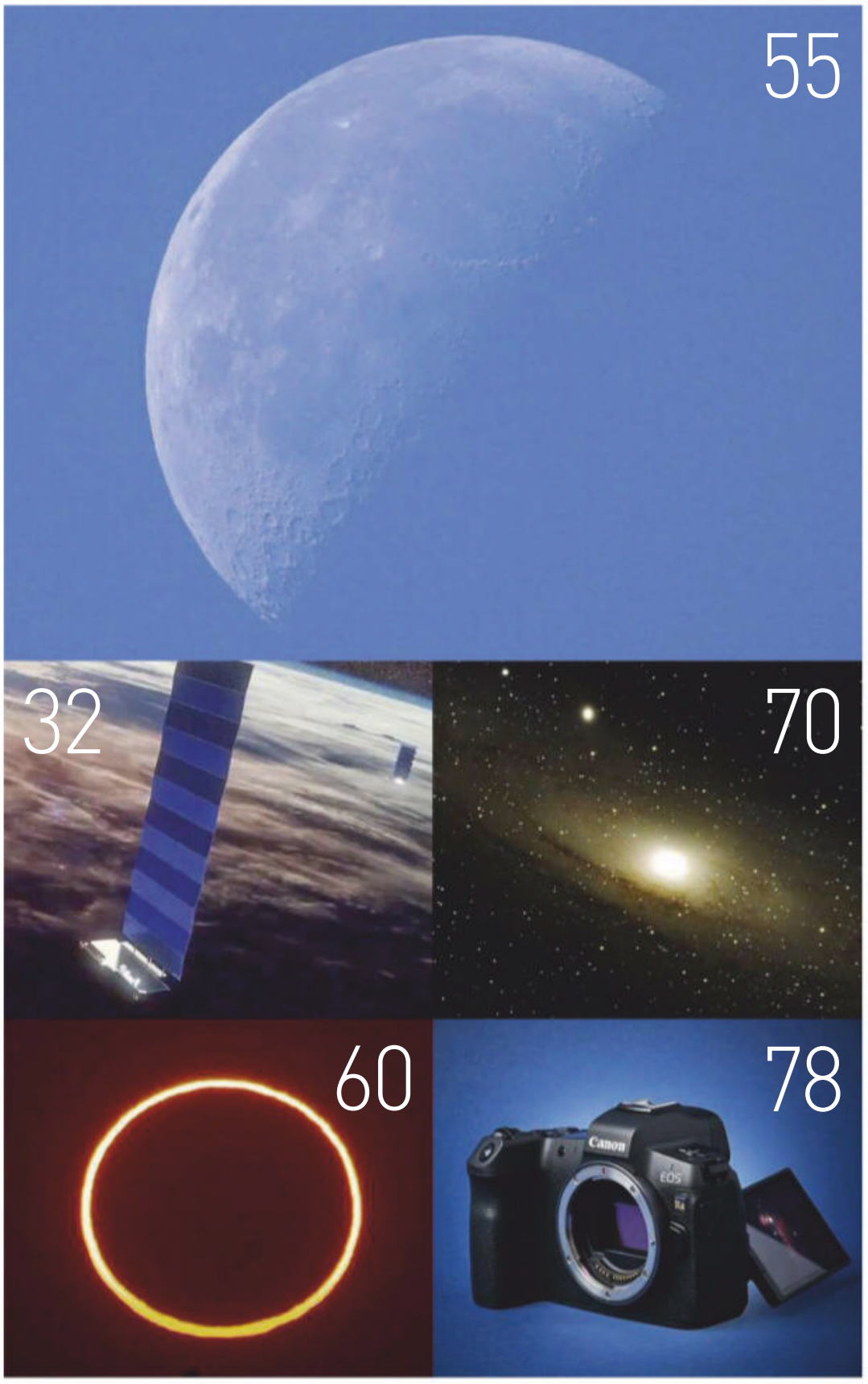
16-PAGE STARGAZING GUIDE

The Sky Guide

COVER MAIN IMAGE: MEINDERT VAN DER HAVEN/ISTOCK/GETTY IMAGES. THIS PAGE: JA'CRISPY/ISTOCK/GETTY IMAGES, SUDA YUICHI/EYEEM/ISTOCK/GETTY IMAGES, SPACE X, CHARLOTTE DANIELS, MATTHEW STARLING/ISTOCK/GETTY IMAGES, @THESHED_PHOTOSTUDIO, BBC

New to astronomy?

To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners



This month's contributors

Jamie Carter

Science Journalist

"I've always loved the idea of the astronomical expedition in history, so I enjoyed delving into plans for some eclipse chasers to visit Tibet to watch a 99.5 per cent ring of fire. **Jamie looks forward to the annular solar eclipse,** page 60

Paul Money

Reviews editor

"It's incredible how much astronomy you can actually do while the Sun is up. Spotting stars during the daytime is a real eye-opener." **Paul points the way to finding planets and stars during daylight hours,** page 55

Ezzy Pearson

News editor

"As I wrote this piece about Starlink, several bright satellite passes happened. It left me wondering whether or not such sights would soon be commonplace." **Ezzy investigates satellite constellations,** page 32

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/QJ59L2J/** to access this month's selection of exclusive Bonus Content.

JUNE HIGHLIGHTS

Watch April's *The Sky at Night*

Lucie Green travels to Kennedy Space Center to see the launch of ESA's new Solar Orbiter spacecraft.

Interview: a new era for exoplanet hunting

Savannah Jacklin on how the WFIRST mission uses a phenomenon predicted by Einstein to find worlds orbiting distant stars.

Audiobook preview: Extraterrestrials

Download and listen to two chapters from a new audiobook that explores the search for intelligent life beyond Earth.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

NASA/ESA/AND STScI

BIRTHDAY BEAUTY

Two contrasting nebulae are captured in an image to mark Hubble at 30

HUBBLE SPACE TELESCOPE, 24 APRIL 2020

A life and death tussle never looked so beautiful. This is the remarkable 'Cosmic Reef', part of the vast Large Magellanic Cloud, the third closest galaxy to the Milky Way.

On the right is NGC 2014, a glowing red cloud of mostly hydrogen gas blown apart by a cluster of hot, newborn stars, unleashing fierce winds and creating structures reminiscent of brain coral.

On the left is its distinctive blue sibling, NGC 2020, formed when a single star – a monster 15 times more massive and 200,000 times more luminous than the Sun – was ejected from the stellar nursery. This short-lived colossus, Wolf–Rayet star HD 269748, is shedding its external envelope in a superbubble of blue gas. In a relatively short time, it will end its life in a supernova.

MORE **ONLINE**

A gallery of these and more stunning space images

△ Rare rings

HUBBLE SPACE TELESCOPE, 6 APRIL 2020

NGC 2273 is a rarity, with an inner ring and two outer 'pseudorings' formed from two sets of spiral arms looping around and appearing to close upon one another. Found 95 million lightyears away in the constellation of Lynx, NGC 2273 is also a Seyfert galaxy with a supermassive black hole at its extremely bright centre.

Final glimpse of Earth ▷

BEPICOLOMBO, 10 APRIL 2020

A thin crescent receding into the distance is BepiColombo's last view of Earth as it makes its way to the smallest and innermost planet of the Solar System, Mercury. Having already travelled almost 1.4 billion kilometres since its launch in October 2018, the flyby was one of several gravity-assisted manoeuvres the ESA/JAXA spacecraft must make in order to hit Mercury's orbit in December 2025.

ESA/HUBBLE & NASA/J. GREENE, ESA/BEPICOLOMBO/MTM, NASA/JPL-CALTECH/SWRI/MSSS IMAGE PROCESSING BY KEVIN M. GILL, ©2019 SETI INSTITUTE, ESA/HUBBLE & NASA/L. HO

◁ Swirling world

JUNO, 10 APRIL 2020

Jet streams produce an exquisite pattern in Jupiter's northern mid-latitude region in this image captured by JunoCam. NASA's Juno has been in orbit around the Solar System's largest planet since 2016. Travelling at around 200,000km per hour and as close as 5,000km above the cloud tops, it is due to deorbit into the planet's interior in July next year.

Dying ATLAS ▷

UNISTELLAR/SETI, 11 AND 14 APRIL 2020

Excitement had been building around Comet ATLAS. Discovered in December, it was on course for naked-eye visibility by May. But, as these images from a joint Unistellar/SETI Institute citizen science project show, it was not to be. Combining data from 60 Unistellar eVscope users in Europe and the US, they revealed the comet to be rapidly dimming as it broke up into several pieces.

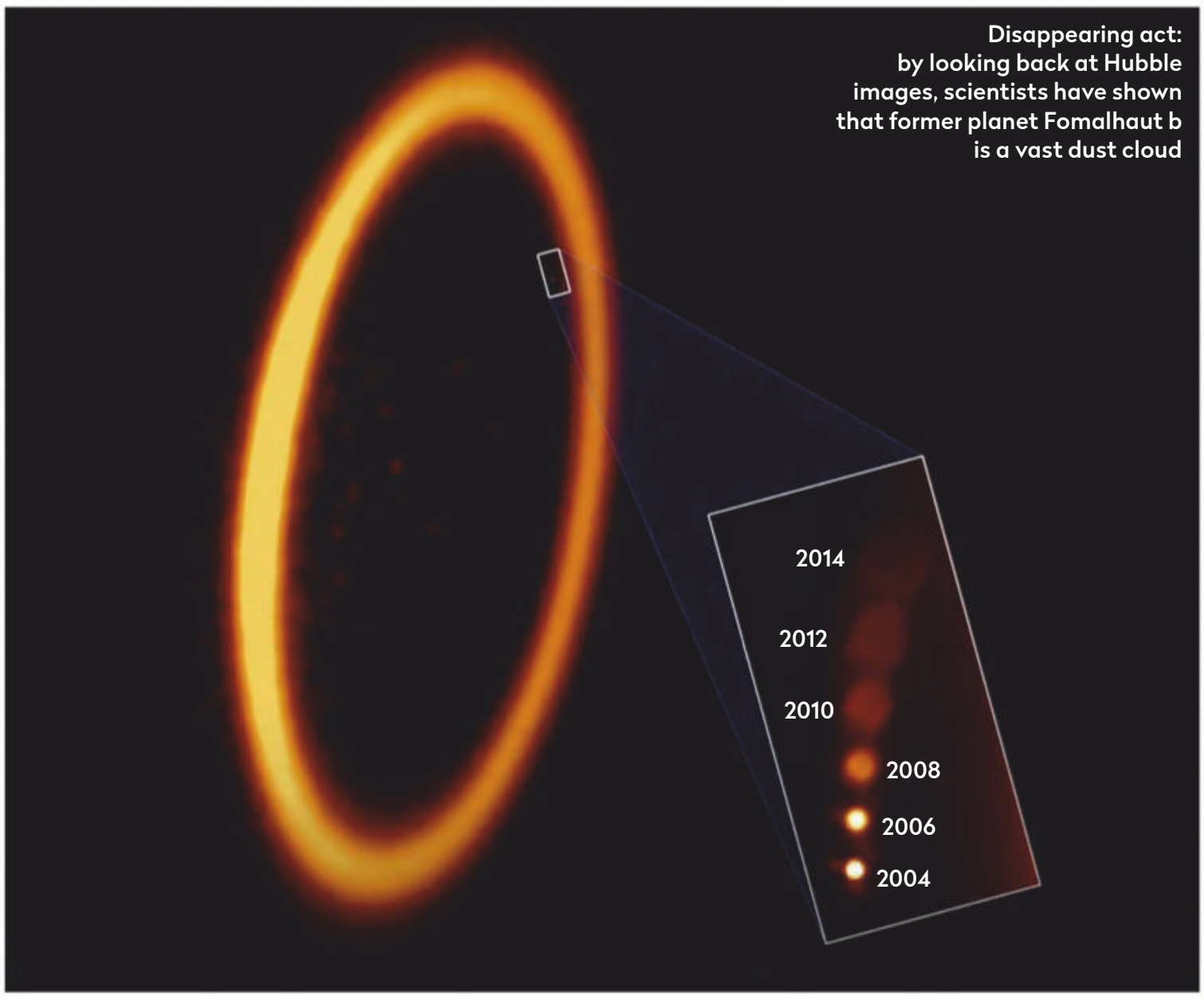
△ Stretched spiral

HUBBLE SPACE TELESCOPE, 27 APRIL 2020

NGC 4100, 67 million lightyears away in Ursa Major, appears from Hubble's line of sight to be stretched across the sky; an elongated spiral punctuated by sparkling blue newborn stars. This image was captured by Hubble's Advanced Camera for Surveys (ACS), installed in 2002 and still going strong thanks to a servicing mission in 2009.

The latest astronomy and space news, written by Elizabeth Pearson

BULLETIN



Disappearing act: by looking back at Hubble images, scientists have shown that former planet Fomalhaut b is a vast dust cloud

NASA/ESA AND P. KALAS (UNIVERSITY OF CALIFORNIA/BERKELEY/USA), NASA/AMES RESEARCH CENTER/DANIEL RUTTER, AIRBUS SPACE, NASA/JPL-CALTECH

‘Planet’ actually rare cosmic collision

A reanalysis of Hubble images reveals an ‘exoplanet’ to be a cloud of dust

What astronomers had previously thought to be an exoplanet might be something rarer – the remains of two comet-like objects which have crashed together.

The former planet, Fomalhaut b, was first announced in 2008 after four years of Hubble observations tracked a bright point moving through the planetary disc of a distant star. At the time, astronomers thought this was a newly formed exoplanet, making it the first one to be detected directly through visual observations. Researchers continued to observe the ‘planet’ every few years as it made its way around the star but were shocked in 2014 to discover that it had vanished.

After looking back at the last decade of observations, a team of exoplanet astronomers realised that Fomalhaut b had actually been fading for several years. They now believe that rather than being a full-fledged planet, Fomalhaut b is actually a cloud of dust created by the collision of two icy objects similar to those found in our Kuiper belt. “These collisions are exceedingly rare and so this is a big deal that we get to see evidence of one,” says Andras Gaspar from the University of Arizona’s Steward Observatory, who led the research.

Astronomers will continue to watch the system to gain an insight into how such cosmic crashes affect the evolution of growing planets.

“We do have evidence of such collisions in other systems, but none of this magnitude has been observed in our Solar System,” says the Steward Observatory’s George Rieke. “This is the blueprint of how planets destroy each other.”

www.hubblesite.org

Comment

by Chris Lintott

So long, then, Fomalhaut b, a planet that never was. Never one to follow convention you confused astronomers, refusing to follow a conventional orbit, and fading slowly over time in an unplanetary fashion. You also appeared to be getting larger as you got older, another sign that you were something other than an ordinary planet.

The scientific literature now regards you as an ex-planet. You will be forgotten as we’re distracted by the glittering presence of thousands of unusual systems that actually exist. But I’ll remember when we thrilled at those Hubble images which, for the first time, showed something moving in orbit around a star other than the Sun.

Chris Lintott co-presents *The Sky at Night*

Looking for signs of life: an artist's impression of the surface of Kepler-1649c

Earth-sized planet found in habitable zone

The planet was nearly ignored after being misclassified

One of the most Earth-like exoplanets ever found has been pulled from anonymity after almost being overlooked.

In a recent paper, a team of astronomers re-evaluated data from the Kepler Space Telescope, looking for potential planetary signals that had mistakenly been thrown out as an unwanted artefact. The uncovered planet, Kepler-1649c, is a world around 6 per cent larger than Earth in the habitable zone of a red dwarf star 300 lightyears away.

"In terms of size and likely temperature, this is the most similar planet to Earth that has ever been found with Kepler," says Jeff Coughlin from SETI Institute, who took part in the study.

"The more data we get, the more signs we see pointing to the notion that potentially habitable and Earth-sized planets are common around these kinds of stars," says Andrew Vanderburg from the University of Texas who led the study.

www.nasa.gov/kepler

Space industry fights COVID-19

As part of the UK's response to COVID-19, Airbus Space is helping to produce 40,000 face shields for the NHS

As the world continues to battle the COVID-19 pandemic, the space sector is on hand to aid in the fight.

In the UK, a fund of £2.6m has been made available to the space industry to help fund high-tech products which might aid the NHS response to the pandemic. These projects include a satellite system helping GPs conduct virtual consultations and software which can diagnose cancer more quickly.

Elsewhere in the world, engineers at NASA's Jet Propulsion Laboratory who normally build spacecraft are instead designing new ventilators specifically designed for COVID-19 patients. Meanwhile, colleagues at Armstrong Flight Research Center have designed a special pressure helmet to treat those with more minor symptoms. "The current circumstances challenge the space business community to show just how much it can offer, to help us through this once in a century event. Speed is of the essence, so let us act without delay," says Nick Appleyard, from ESA's European Centre for Space Applications and Telecommunications.

bit.ly/space-agency

NEWS IN BRIEF

Perseverance gets a helicopter

NASA engineers attached the Mars Helicopter Delivery System to the Perseverance rover (formerly Mars 2020) on 6 April. The system is a prototype of an airborne planetary explorer which could be used to explore the Martian skies. The mission aims to launch this summer and reach Mars in February 2021.

Crowd-sourced comet

Dozens of home astronomers held virtual star-parties on 11 and 14 April to observe Comet ATLAS as it broke apart. The group were all using special digital telescopes from Unistellar which allowed them to easily share their data and combine it to create one mega-image.

Galactic catapult

Supernovae near the edge of the Milky Way could be launching stars into the halo surrounding our Galaxy, according to a new set of simulations. "When multiple big stars die, the resulting energy can expel gas from the Galaxy, which in turn cools, causing new stars to be born," says James Bullock from the University of California who led the study.

Keeping cool: research into Comet 21/Borisov, an interstellar visitor to our Solar System, reveals vital clues about its origins

Comet Borisov has high levels of carbon monoxide

The presence of the chemical suggests the comet hails from a much colder climate

Interstellar comet 2I/Borisov has been found to have high levels of carbon monoxide, giving a hint to what kind of planetary system it originated from.

The recent discovery came after astronomers analysed images from the Hubble Space Telescope, taken when the comet flew through the Solar System in late 2019. Borisov attracted the attention of astronomers after its trajectory suggested it started life around another star. As comets are thought to be the icy remnants of when the planets first formed, it gave planetary scientists a unique chance to look at some of the chemical building blocks of another planetary system.

"We've been studying the composition of comets here for decades and using this information to understand how planets in our Solar System formed and evolved," says Kathleen Mandt from the Johns Hopkins University, who took part in the study.

While astronomers believe they have found a few comets in orbit around other stars, they are too far away to learn anything detailed about their composition. Borisov, however, was close enough for telescopes to measure. Using Hubble's ultraviolet instruments, astronomers were able to gauge how much water, oxygen, carbon dioxide and carbon monoxide the comet possesses.

After months of analysis, the team have now studied some of these observations, revealing that Borisov has 50 per cent more carbon monoxide than water. As carbon monoxide is a volatile compound, which boils away when exposed to heat or sunlight, the chemical's abundance gives a clue about where the comet originated.

"The high amount of carbon monoxide is an indication that it comes from a very cold place, either extremely far away from its host star or from a relatively cold star," says Jian-Yang Li from the Planetary Science Institute who helped lead the observations. "We think it's more likely to be the latter case and it comes from a cold red dwarf, because there are far more red dwarfs in our Milky Way than other hotter stars. However, we are still far from saying exactly what was going on around its host star when planets formed there."

https://hubblesite.org/

NASA/ESA/AND D. JEWITT (UCLA), NASA, X-RAY: NASA/CXO/CSIC-INTA/G.MINIUTTI ET AL/ILLUSTRATION: NASA/CXC/M. WEISS, JOHAN63/ISTOCK/GETTY IMAGES

▲ Back to the Moon: an artist's impression shows astronauts in NASA's Artemis programme

NASA selects lunar lander developers

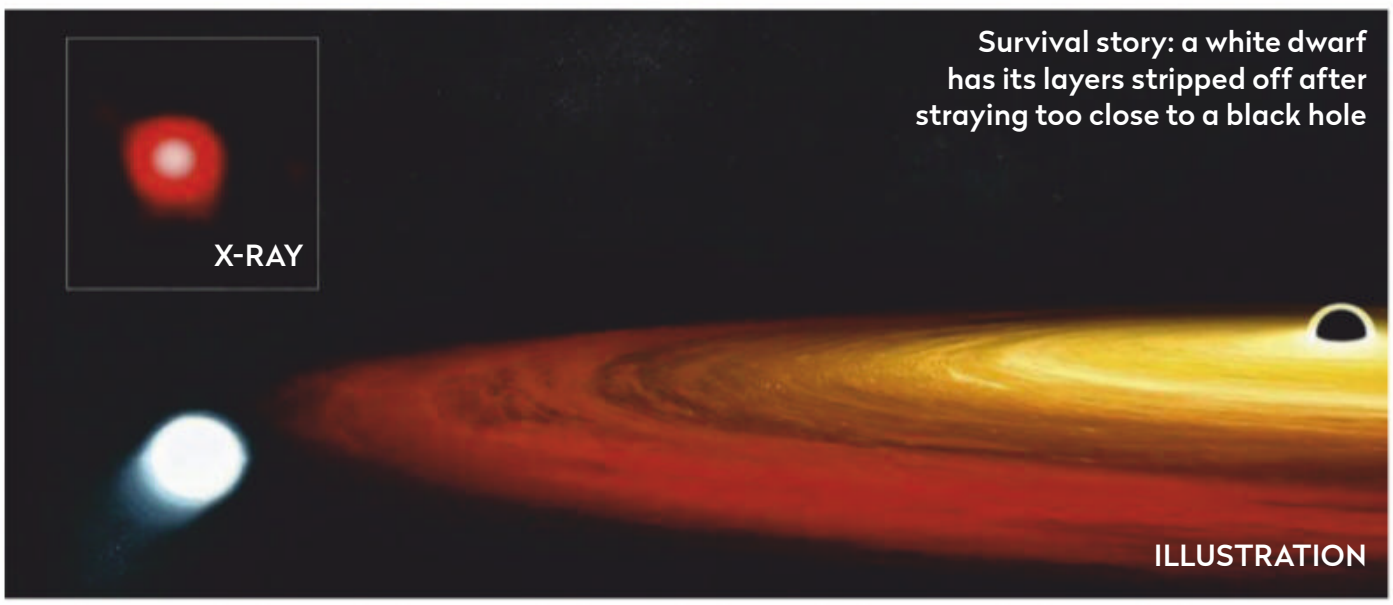
Three companies are designing their own version of the vehicle

NASA has taken another step towards returning to the Moon by contracting Blue Origin, SpaceX and Alabama-based Dynetics to build the next generation of lunar landers, the agency recently announced. The three spaceflight companies have each been tasked with designing and building a new landing system that will carry astronauts to and from the lunar surface. The move is part of the space agency's Artemis programme – an initiative aiming to return astronauts to the Moon, one of whom will be the first female moonwalker, by 2024.

"We are on our way," says Douglas Loverro, associate administrator for NASA's Human Explorations and Operations Mission Directorate. "With these awards we begin an exciting partnership with the best of industry to accomplish the nation's goals. We have much work ahead, especially over these next critical 10 months. I have high confidence that working with these teammates, we will succeed."

www.nasa.gov

Black hole nibbles on star



Survival story: a white dwarf has its layers stripped off after straying too close to a black hole

A star has survived a close brush with a black hole, only to be slowly devoured. Recent observations from X-ray telescopes Chandra and XMM-Newton have revealed the dramatic story of a red giant which drifted too close to the black hole at the centre of its galaxy. The star was captured by the black hole, which then stripped away the outer layers of the red giant's gas until only a white dwarf remained.

The black hole continues to nibble away the star's gas, creating bright bursts of X-rays as it does so. As the star continues to lose mass, it slowly drifts away, but it will never quite escape the black hole's grasp.

"The black hole will eat it more and more slowly, but never stop," says Andrew King from the University of Leicester, who led the study. "In principle, this loss of mass would continue until and even after the white dwarf dwindled down to the mass of Jupiter, in about a trillion years. This would be a remarkably slow and convoluted way for the Universe to make a planet!"

http://chandra.si.edu

NEWS IN BRIEF

Interstellar asteroids

A population of asteroids currently residing between the outer planets appears to have originated around another star, a new report has found. The space rocks started life around one of the stars which shared the Sun's stellar nursery. Their close proximity meant that asteroids could easily slip between the planetary systems.

Starlink reaches 400 satellites

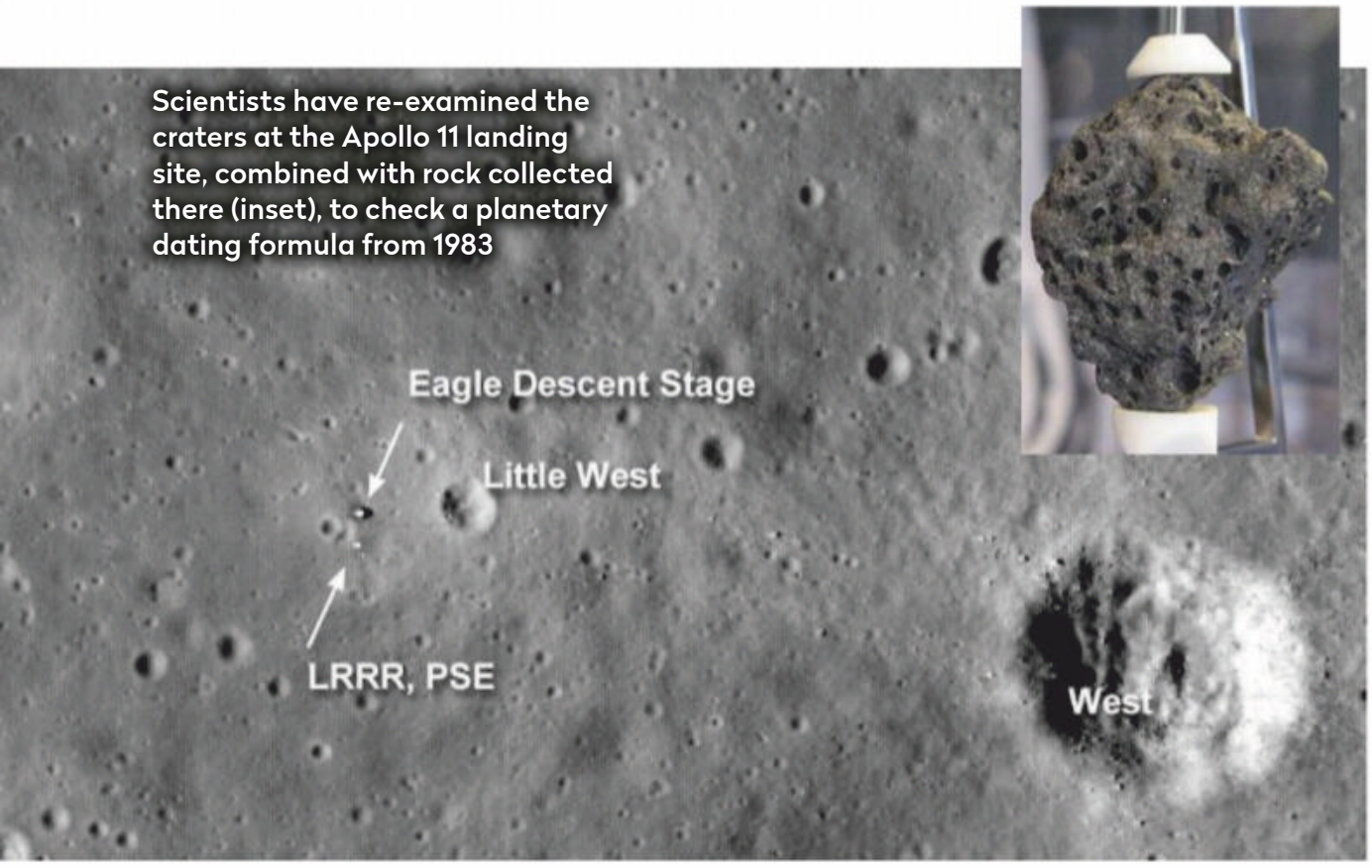
On 22 April, SpaceX delivered its latest batch of Starlink satellites into orbit, bringing the total to over 400. Elon Musk has previously stated this is the number needed for the network to begin supplying high-speed internet to the Northern Hemisphere. To find out more about the Starlink project, turn to page 32.

Science begins for CHEOPS

ESA's CHEOPS space telescope began its scientific operations in early April. The observatory will examine exoplanets and attempt to pick out what chemicals are present in their atmospheres to better understand what these worlds are like.

Our experts examine the hottest new research

CUTTING EDGE



Scientists have re-examined the craters at the Apollo 11 landing site, combined with rock collected there (inset), to check a planetary dating formula from 1983

NASA/GSFC/ARIZONA STATE UNIVERSITY, NASA, HUBBLE/NASA/ESA/M. KORNMESSER

Crater counting correctly

After 40 years, scientists are re-evaluating how they date the ages of planetary surfaces

When planetary scientists are trying to understand the surfaces of other worlds in our Solar System, and the processes that form and shape them, the ages of different features is a crucial detail.

It's straightforward to deduce the relative chronology of different plains of volcanic rocks or sedimentary deposits by looking to see which one appears to lie on top of or cut across the other. But this only tells you that one splodge of rock is older or younger than its neighbouring formations. What would be so much more useful to know is the absolute age of particular surfaces – for example, this volcanic plain is 200 million years old, but that one erupted only 60 million years ago.

On Earth, one of the main methods we use to date the formation of geological strata is to measure the amounts of different radioactive isotopes the rock contains. Unfortunately, when it comes to our exploration of other planets, this sort of measurement is currently impossible for the instruments aboard lander probes such as the Curiosity rover on Mars.

Luckily, planetary scientists do have a simple trick up their sleeve. In general, the older a planetary surface is, the more impacts it will have been exposed to. Craters accumulate over time like raindrops on a paving slab during a light drizzle, and so finding relative ages becomes a process of crater-counting. But in order to calculate a much more useful estimate of the absolute age of a surface, you also need to know the rate that impacts of different sizes occur through the Solar System. And this is why the Apollo Moon missions were so valuable.

Testing the formula

The Apollo crews collected rock samples from known locations on the lunar surface and brought them back to labs on Earth so that the radioactive isotopes could be measured. Planetary scientists could then match up these radiometric ages with crater-counts of the same surface, and so derive a formula that allows us (with some adjustments) to calculate the absolute age of surfaces throughout the Solar System.

Huge amounts of current planetary science is based on these Apollo samples from 50 years ago, and the dating formula published in 1983. But we now have better images of the lunar surface for crater counting, and more precise isotopic measurements of the recovered rocks.

"We have better images of the lunar surface for crater counting, and more precise isotopic measurements of the Moon rocks"

And so Wajiha Iqbal and her colleagues from the University of Münster thought it was time for a reassessment of these calculations.

Iqbal has spent her PhD using ultra high-resolution Lunar Reconnaissance Orbiter images to generate geological maps of the Apollo 11 landing site and to count craters. She correlated these with recent measurements of radiometric ages for Apollo rock samples, and compared her updated chronology formula with that of 1983.

And the answer? Absolutely no change. The 1983 chronology formula was bang-on. Which, far from being an anti-climax, is wonderful. It means nothing needs to be recalibrated from almost 40 years of planetary research, but we only have this scientific confidence if established results are double-checked. If we never confirmed what we thought we already knew, we'd not spot curious anomalies that could hint at some new science lurking unseen below the surface.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Geological Mapping and Chronology of Lunar Landing Sites: Apollo 11* by Wajiha Iqbal. **Read it online at https://arxiv.org/abs/2003.03292**

Finding the middle ground

Could astronomers have finally found the 'missing link' of black holes?

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

We know that most, if not all, galaxies have supermassive black holes at their centres. Though they can't be seen directly, evidence comes from observing the behaviour of stars and gas, most strikingly at the centre of our own Milky Way where observations taken each summer for more than 20 years reveal the orbits of stars about the galactic centre. With a mass equivalent to nearly four million Suns, this is truly a supermassive black hole, but astronomers have struggled to explain how it came into being.

We know how at least some black holes form. Rigel, in Orion, has a mass about 18 times that of the Sun. When, in a few million years' time, it exhausts the fuel at its centre, a spectacular supernova will be the result. Most of the star's material will be scattered to the galactic winds, but the core will collapse, forming a small black hole, one which will weigh in at a few times the mass of the Sun. Evidence of such stellar mass black holes has been gathered over the last few decades, most spectacularly in the minuscule ripples in space recently detected by gravitational wave experiments and due to the collision of black holes.

Black hole quest

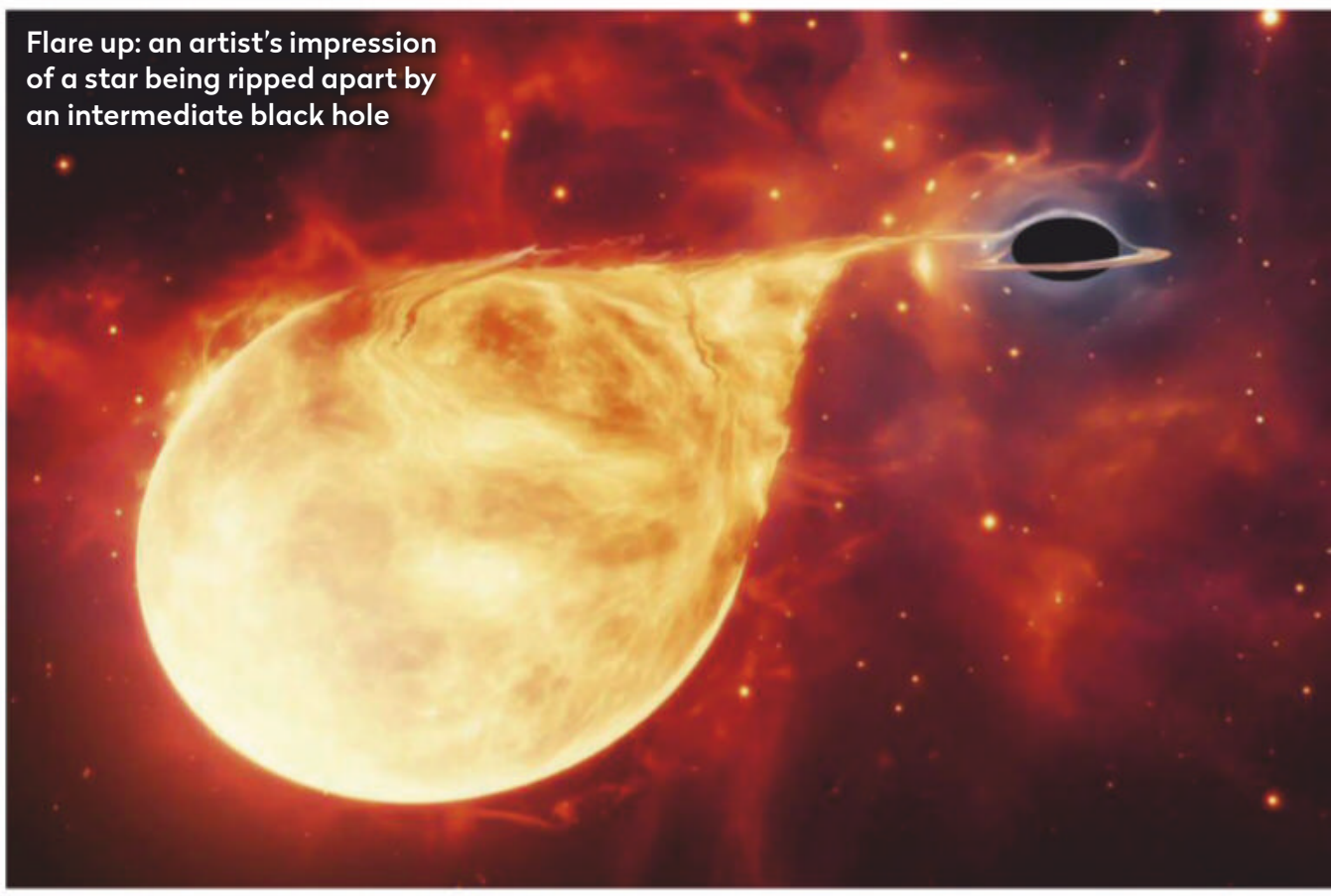
Gravitational wave experiments are most sensitive to the collision of massive black holes but have not seen evidence for anything much more massive than maybe 50 solar masses. That fits with our understanding of stars and supernovae, which predicts a maximum mass which falls well short of that obtained by the sort of behemoths that lurk at the centre of galaxies. In seeking to understand how such massive objects form, astronomers have long sought our 'missing link' – a population of black holes intermediate in mass between the two.

"The burst of X-rays might indicate the presence of the elusive intermediate mass black hole"

Now results from a new paper suggest that the quest might have succeeded.

The object in question is 3XMM J215022.4-055108 (catchy, I know), a source of X-rays which suddenly flared up in 2006. Such a flare indicates that something dramatic is happening; in this case, we seem to have captured the final moments of a star being ripped apart by the gravitational pull of a black hole. Such things happen from time to time – a disruption to the delicate dance in the Milky Way's centre could send its orbiting stars into harm's way – but this particular flare did not come from the centre of a galaxy where supermassive black holes may be assumed to be lurking, and it was bright enough that a stellar-sized black hole would be an unlikely progenitor.

That burst of X-rays might therefore indicate the presence of the elusive intermediate mass black hole, but there remained the possibility of a false alarm. The signal could have been coming from a less luminous source in the Milky Way itself. Using the orbiting Hubble Space Telescope, the location of the X-ray source has now been pinned down. The emission comes from a star cluster on the edge of a distant galaxy, a likely home for intermediate black holes. The missing link may have been found at last.

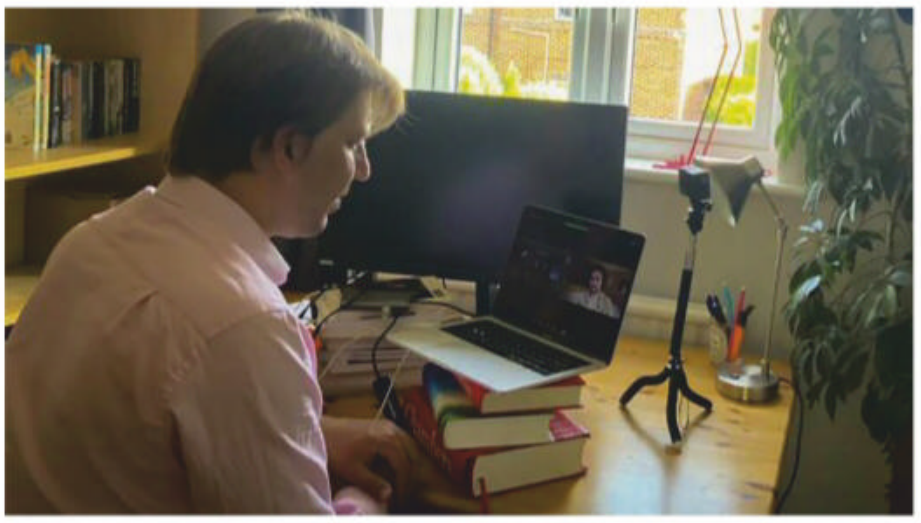


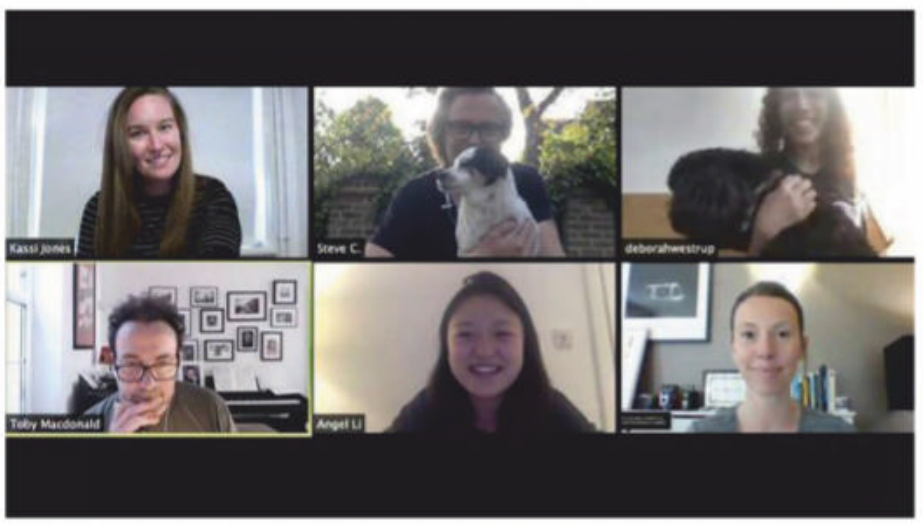
Flare up: an artist's impression of a star being ripped apart by an intermediate black hole

Chris Lintott was reading... *Multiwavelength Follow-up of the Hyperluminous Intermediate-mass Black Hole Candidate 3XMM J215022.4-055108* by Dacheng Lin et al. **Read it online at: https://arxiv.org/abs/2002.04618**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT





The Sky at Night's executive producer **Steve Crabtree** reveals how they made the 800th episode of the show without anyone leaving home

▲ Filming under lockdown: (clockwise, from top left) at home with presenters Chris Lintott and Maggie Aderin-Pocock; a remote meeting of *The Sky at Night* production team; and Pete Lawrence presents from his back garden

CHRIS LINTOTT, MAGGIE ADERIN-POCOCK, PETE LAWRENCE, BBC, NASA/ESA AND M. KORNMESSER, NASA, BBC

A few weeks ago no one could have predicted the way we would produce this month's *Sky at Night* programme – our 800th – or how much it would change from the original plan.

We were going to send Maggie and Chris to Chile, as guests of the European Southern Observatory, to look at the optical telescopes they operate in the Atacama desert; and to report on the progress of the Extremely Large Telescope – soon to become 'the world's biggest eye on the sky'. Of course, events took over and we had to postpone the trip due to the COVID-19 pandemic, though we're still hoping to film later in the year when everything returns to normal.

Instead, our amazing production team ended up making a very different programme from the one we had planned. In many ways our 800th episode couldn't be more appropriate for the time it was made.

After cancelling our trip to Chile we had to decide what would replace it; following both government guidelines and the BBC's own strict rules we decided not to travel. In fact many, if not all of the universities, museums and observatories we would normally film with have quite rightly closed their doors.

We already had some idea of what it would be like putting together a show remotely from April's episode on the Solar Orbiter mission. Though we'd filmed the episode before lockdown, it was edited together afterwards. Our outgoing series producer, Simon Winchcombe, had left us with a wealth of useful insights into completing a television programme without anybody having to leave the house (Chris Lintott even recorded his voiceover for the show from a makeshift sound booth that included a duvet slung over a couple of cushions in his front room).

Incoming series producer, Toby Macdonald, came up with the idea that as our 800th episode would be made remotely, it should be about working remotely, something many astronomers do on a daily basis. We also included a project our viewers could actively participate in and there was a treat at the end for our fans to celebrate 800 episodes – tune in again on iPlayer to find out what those are!

Once we had our 'running order' of what would be in the programme, our assistant producer Angel Li set

Steve Crabtree is executive producer of *The Sky at Night*

up interviews and wrote the script, while our archive producer Deborah Westrup sourced the material we hadn't filmed ourselves (such as animations or satellite imagery) to illustrate some of our stories.

To do the recording, we sent cameras, microphones and various other pieces of kit to our three main presenters: Chris Lintott, Maggie Aderin-Pocock and Pete Lawrence. They filmed themselves – with Toby remotely directing – and then sent the material to our film editor Tracy Joss – who cut the programme in her edit suite at home, with Toby by her side – virtually of course – shaping the show and writing the commentary.

My responsibility is to oversee the production, along with Kassi Jones our production manager, and Alice Groman the production coordinator, who ensures that everything is delivered on time, on budget, meets the BBC's standards and is ready to transmit on schedule.

There were one or two surprises in the programme that I'm sure our viewers will enjoy and that make this particular episode memorable. I think we have produced an incredible programme; certainly made in extraordinary circumstances – but I know our loyal viewers will appreciate the dedication of the team – both on and off screen – to bring them their monthly guide to the sky at night.

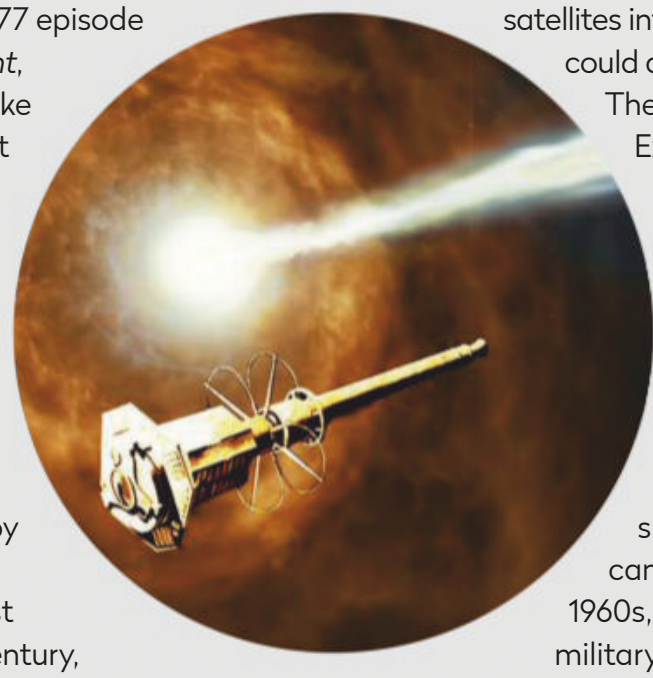
Looking back: The Sky at Night

June 1977

On the 28 June 1977 episode of *The Sky at Night*, Patrick Moore spoke with astrophysicist Jocelyn Bell Burnell about the rapidly expanding field of gamma-ray astronomy.

Gamma rays are high energy photons created by equally energetic events. For the first half of the 20th century, astronomers theorised that violent events such as supernovae could produce gamma rays. However, Earth's atmosphere does a good job of absorbing such radiation, making it difficult to observe the rays from the ground.

By the early 1960s, astronomers were finally able to put gamma-ray detecting satellites into orbit, where they could detect the rays.



▲ **NASA's Explorer 11 was the first satellite launched to detect gamma rays**

The first was NASA's Explorer 11, which picked up 100 photons coming from all over the Universe, suggesting some kind of gamma-ray background.

The most surprising discovery came in the late 1960s, when a set of military satellites designed to detect the gamma emissions of nuclear bombs detected flashes of gamma rays lasting from a few seconds to a few minutes coming from deep space. These bursts have since been tracked back to distant galaxies and are thought to come from the highly energetic supernovae.

The show must go on

Due to the uncertainty surrounding the COVID-19 pandemic and the fact that the UK is currently under lockdown, planning, recording and producing *The Sky at Night* is an uncertain process at the moment. But Maggie, Chris, Pete and the rest of the team are working hard to ensure the programme airs on BBC Four in its regular slot this month, bringing you the latest adventures in spaceflight and practical astronomy.

BBC Four, **14 June**, 10pm (first repeat BBC Four, **18 June**, 7.30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

Though they can't be together, the *Sky at Night* team will continue to make inspiring episodes

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

Finding Venus

This month's top prize: four Philip's books

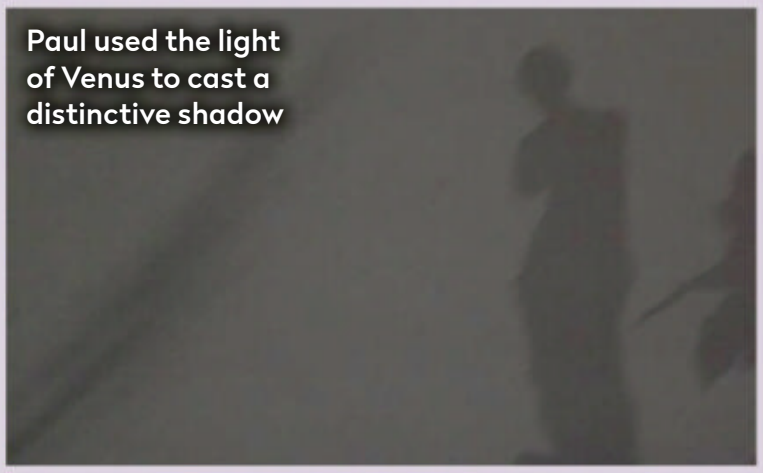
PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, and Heather Couper and Nigel Henbest's *2020 Stargazing* and a planisphere for the night skies at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

I decided to try the Sky Guide Challenge of capturing the shadow of the light cast by Venus (April issue, page 55), so I rigged up a large sheet of white paper in my kitchen and attached a cut out of the Venus de Milo to the window. Over the course of two nights I set up my Canon 70D and 50mm lens on Bulb (B) mode and tried a few test images beginning around 10pm. I found that f/1.8, ISO 2500 and a 60" exposure looked okay on the camera screen, but Photoshop showed it needed stretching. The two images (right) were taken five minutes apart; as you would expect from the setting Venus, the image moves up and to the right. To misquote the Beatles, 'She came in through the kitchen window, projected on a paper screen.'

Paul Mundell, via email

Very well done, Paul. With your entirely fitting choice of object to cast the shadow, you've met the Sky Guide Challenge with real creativity! ***– Ed.***


Paul used the light of Venus to cast a distinctive shadow

Tweet

John M
@johnmason1971 • Apr 20
My 5yr old, enjoying the pics in @skyatnightmag although some of the content is a little beyond her. #Homeschooling2020

Timely warning

With time on my hands, I was rereading your February 2013 issue. One of the books reviewed was *Megacatastrophes! Nine Strange Ways the World Could End*. One of the co-authors, David Darling, answers a couple of questions:

S@N: What's the most likely way the world will end in your opinion?
DD: There isn't any way the planet itself is likely to be destroyed until the Sun expands to become a red giant in several billion years' time. Among the catastrophes that could wipe out much of the human race, our highest ranking goes to an untreatable global pandemic, such as a mutant flu strain or an Ebola-like virus that spreads around the world before quarantine can be put in place.
S@N: Could any of these events happen in the next decade or so?
DD: The only one that poses a significant risk over the next 10-20 years is a pandemic. Some events, such as super-volcanoes, aren't predictable and so could happen at any time. But the probability is low.

Prescient or what?

Pete Collins, via email

Lockdown mount

Seeing your review of the binocular parallel mount in the May issue ('First Light: Orion Monster Parallelogram mount and GiantView 25x100 binoculars kit', page 90) I thought you'd like to see the mount I made during the COVID-19 lockdown. Based on a design from the magazine back in 2013 ('How to',

Inspired: Alan dipped into magazine back issues from 2013 to help build his binocular mount

September and October 2013, issues 100 and 101) with a few tweaks and improvements. The total cost was around £100 in materials, plus quite a few hours labour (not counting the 15x80 binoculars!).
Alan Beech, via email

Light relief

As a reader who lives in an area of suburban street lighting, one of my favourite sections of *Sky at Night Magazine* is the 'Binocular Tour' in the 'Sky Guide', whose objects are bright enough not to be washed out. This is especially true in a time hen I cannot get out into the countryside due to the lockdown.

In the April 2020 issue (on page 54) I enjoyed the 'Three Leaps of the Gazelle', not only because of the story but because of the lovely colours of some of the stars that form the hoof prints. I am really looking forward to when I can see my grandchildren again so I can share the story and the colours with them.
Jeff Mason, Stockport ▸

ON FACEBOOK

WE ASKED: How has lockdown affected your astronomy?

Nick Martell I have always had an interest in astronomy but the lockdown has changed this for me to a much higher degree. I am outside every night now and being just an amateur I am starting to learn the sky. Once lockdown is complete I will be looking for my first telescope.

Sarah MacGregor It's enabled me to rediscover the spark and passion I had for astronomy as a child... so much so my husband has bought me my first telescope and I am now so excited to be able to share this new adventure of discovery with my family.

Tony Horton My being furloughed from work has coincided with a period of excellent weather. I've been imaging from my observatory and I've also had the Dobsonian out in the garden. No work means no morning alarm clock!

Nick Williams Reduced air traffic has made for much more transparent skies, especially over where I live in London. I've taken advantage of this to image the Whirlpool Galaxy.

Tony Moss I miss meeting up with all the other members of our local astronomy club.

Carol Barchou I've been out quite a few nights and have loved watching the Starlinks go over. Venus has been beautiful and the Moon last night was amazing. I'm thinking of buying a telescope...oh dear!

Ron Hardington Having been meaning to purchase a telescope for a number of years I have now taken the plunge. Looking forward to setting it up for my family to be inspired.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have an inexpensive telescope which struggles to hold focus. Do you have any suggestions of how I can improve things?

JON ELLIS

Focusers can be locked in place with the thumb bolt

Your telescope, an Aspen model F500/D114, is a Newtonian reflector badged for sale by several companies as an entry-level instrument. It has a very basic and rather coarse rack and pinion focuser, but these don't normally slip.

On the top of the focuser casting, you will find a knurled thumb bolt and this can be used to both increase the tension on the focus adjustment and lock the focus tube in place. If this is missing from your focuser, you should seek out a replacement. However, if the bolt is in place, the best method of achieving and maintaining focus is to rack the focuser outwards, passing through the focus sweet spot, and then rack it back in again until the best focus is achieved. You can then tighten the thumb bolt to lock the focus tube in position.

Because changes in temperature cause telescope components to expand and contract, you will need to do this at the start of every observing session and from time to time during the session.

Steve's top tip

What is vignetting?

Vignetting is the visible reduction in image brightness towards the edges of a field of view when observed through a telescope. Vignetting is caused by the lens or mirror design, or an obstruction in the light path itself.

Telescopes bend the light that passes through them, forming a cone of light that creates a circular image at the focus point. However, there is always a brighter central region in the cone followed by light fall-off towards the edges.

Anything that intrudes into the light cone will also attenuate the light, so telescope designers go to great lengths to produce wide aperture focusers and adaptors that won't obstruct the view.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

BBC Sky at Night Magazine is published by Immediate Media Company Bristol Limited under licence from BBC Studios, which helps fund new BBC programmes.

EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editor Neil McKim
News Editor Elizabeth Pearson
Staff Writer Iain Todd
Reviews Editor Paul Money

CONTRIBUTORS
Stuart Atkinson, Nisha Beerjeraz, Jamie Carter, Charlotte Daniels, Lewis Dartnell, Glenn Dawes, Jane Green, Martin Griffiths, Pete Lawrence, Chris Lintott, Steve Richards, Phil Sowels, Giles Sparrow, Paul Sutherland, Steve Tonkin, Jane Williamson, Jenny Winder, Paul Wootton

ADVERTISING SALES
Advertising Manager Sam Jones +44 (0)117 300 8145, sam.jones@immediate.co.uk
Inserts Laurence Robertson +353 (0)87 690 2208

PRODUCTION
Production Director Sarah Powell
Production Coordinator Derrick Andrews
Ad Services Manager Paul Thornton
Ad Coordinator Florence Lott
Ad Designer Parvin Sepehr
Reprographics Tony Hunt, Chris Sutch

LICENSING
Director of Licensing and Syndication Tim Hudson
International Partners' Manager Anna Genevier

MARKETING
Head of Circulation Rob Brock
Head of Marketing Jacky Perales-Morris
Marketing Executive Kellie Lane
Press and PR Manager Emma Cooney

PUBLISHING & MANAGEMENT
Publisher Jemima Dixon
Managing Director Andy Healy
Group Managing Director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, Editorial Review Boards Nicholas Brett
Managing Director, Consumer Products and Licensing Stephen Davies
Head of Publishing Mandy Thwaites
Compliance Manager Cameron McEwan
UK Publishing Coordinator Eva Abramik
UK.Publishing@bbc.com; www.bbcstudios.com

EDITORIAL REVIEW BOARD
Andrew Cohen, Head, BBC Studios Science Unit; Deborah Cohen, Editor, BBC Science Radio; Steve Crabtree, Executive Producer, BBC Studios; Carmen Pryce; Robin McKie

SUBSCRIPTION RATES
Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

We abide by IPSO's rules and regulations. To give feedback about our magazines, please visit immediate.co.uk, email **editorialcomplaints@immediate.co.uk** or write to The Editor, *BBC Sky at Night Magazine*, Immediate Media Co., Eagle House, Colston Avenue, Bristol, BS1 1EN.

Audit Bureau of Circulations
17,385 (combined; Jan–Dec 2019)

ISSN 1745-9869

Supermoon snap

▸ I am 16 years old and love your magazine, buying it every month. The book reviews and articles about the recent developments in the field are my favourite parts. I took this image of the supermoon on 7 April at 21:15 BST, using a Meade ETX-90 and an iPhone 6, from Pickmere in Cheshire. It was edited slightly to improve contrast and sharpness using the phone's in-built editing features.
Elliot Hepplewhite-Ford, via email

CORRECTIONS

In the 'Edwin Hubble' section of the feature 'Hubble turns 30' on page 33 of the May 2020 issue, the accelerating expansion of the Universe is attributed to dark matter, when it is dark energy that scientists put the acceleration down to.

On page 39 of the May 2020 issue Shaoni Bhattacharya is credited as the author of *Secrets in the Skies: Galileo and the Astonishing Solar System*. The book's authors are Giles Sparrow and James Weston Lewis.

In the table of brightest comets on page 65 of the May 2020 issue, Comet C/2006 P1 McNaught's peak magnitude is given as +5.5, when its peak magnitude was –5.5.

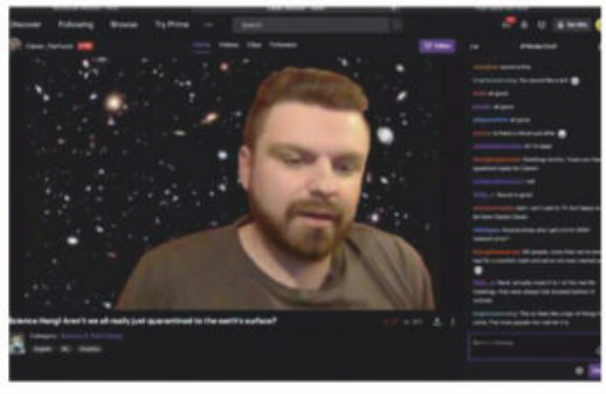
In the caption of the image of a Kreutz comet on page 66 of the May 2020 issue, the SOHO spacecraft was described as a NASA mission, when it is a joint ESA/NASA endeavour.

SOCIETY IN FOCUS

At **Brighton Astro** we'd been having a run of bad luck with our public astronomy events. First there were February's weekend storms and then, just as the weather had started to improve, COVID-19 appeared.

These are strange times for us, as they are for every other astronomy society. We've had to cancel all of our planned monthly meetings and our stargazing evenings. But we decided that just because we can't gather physically it doesn't mean we can't learn about the cosmos. With help from our friends in the Physics and Astronomy department at the University of Sussex we've been organising virtual meetings, where members of our group can watch an astronomy talk broadcast live online.

Our first talk, hosted by astronomer Ciaran Fairhurst (right), was a huge success. Over 100 people tuned in to hear about his research. There are lots of different options for hosting a talk online. We've chosen



Twitch so that people can watch by clicking a link, without having to install software.

Moving our talks online means we're able to offer them to a wider audience and we're not limited to the 60 people per month who can fit into our meeting place. It's important for us to continue to support our local community so we're all doing what we can to keep spirits up and keep in touch. It's just a shame we've had to cancel our pub visits – they're more difficult to recreate online.
Pete Goodman, co-founder
Brighton Astro
▸ **brightonastro.com**

COVID-19

How to get your astro fix from your own home

We pick the best astronomy events and resources available online this month

WHAT'S ONLINE

FILMS

Apollo 11

Boggle all over again at the sheer enormity of the first Moon landing in this feature-length 2019 documentary, packed with gripping behind the scenes footage and newly discovered audio.

netflix.com/watch/81078076

WEBSITES

NASA at home

There are tons of activities on NASA's website for these stuck-at-home times, including ebooks, astronaut tips for living in close quarters, podcasts, ringtones, STEM resources and citizen science opportunities. **www.nasa.gov/specials/nasaathome/index.html**

Meteorwatch.org

@VirtualAstro on Twitter and the website meteorwatch.org are worth following for alerts and tips on International Space Station passes, plus advice on imaging them. **meteorwatch.org**

CITIZEN SCIENCE

Galaxy Cruise

Get onboard the National Astronomical Observatory of Japan's project to classify galaxies. Designed like a game, you complete training to earn your 'boarding pass' before exploring 10 regions, earning 'souvenirs' and passport stamps as you progress.

https://galaxycruise.mtk.nao.ac.jp

ONLINE COURSES

Star Trek

This free 7-week course from the Smithsonian Institution explores the deep influence the futuristic sci-fi show *Star Trek* has had on society and technology. **bit.ly/startrekinspiring**

PICK OF THE MONTH

▲ **Watch this space: kids will enjoy these space-themed *Let's Go Live* episodes on YouTube**

Mission Space

If you're looking for some fun but educational content to keep your young intrepid astronauts occupied, these five Mission Space episodes from children's science presenters Maddie Moate and Greg Foot could be just the ticket.

Best suited to kids of 10 and under, they're part of the *Let's Go Live* YouTube video series with a mix of facts, guests, quizzes and hands-on craft activities. The episodes are: Mapping the Solar System, How to Make a Fruit Salad Solar System, Live Tour of a Spacesuit, Three DIY Rockets to Make at Home and Landing on Another Planet.

It live streamed in April and although the interactive chat is no longer active, the episodes still make entertaining viewing. The craft activities are simple and thankfully involve items you'll likely already have around the house. Presenters (and partners) Moate and Foot have great chemistry and keep the energy up throughout the half-hour shows. But their galactic adventures have lots of solid science substance too, with plenty of take-away knowledge that will stick in young minds.

www.youtube.com

ONLINE INTERVIEWS

BBC Sky at Night Magazine

Our fantastic interviewees include astronaut Scott Kelly, ISS commander Chris Hadfield and NASA engineer Jack Clemons. Catch up on the video interviews here:

bit.ly/skyatnightinterviews

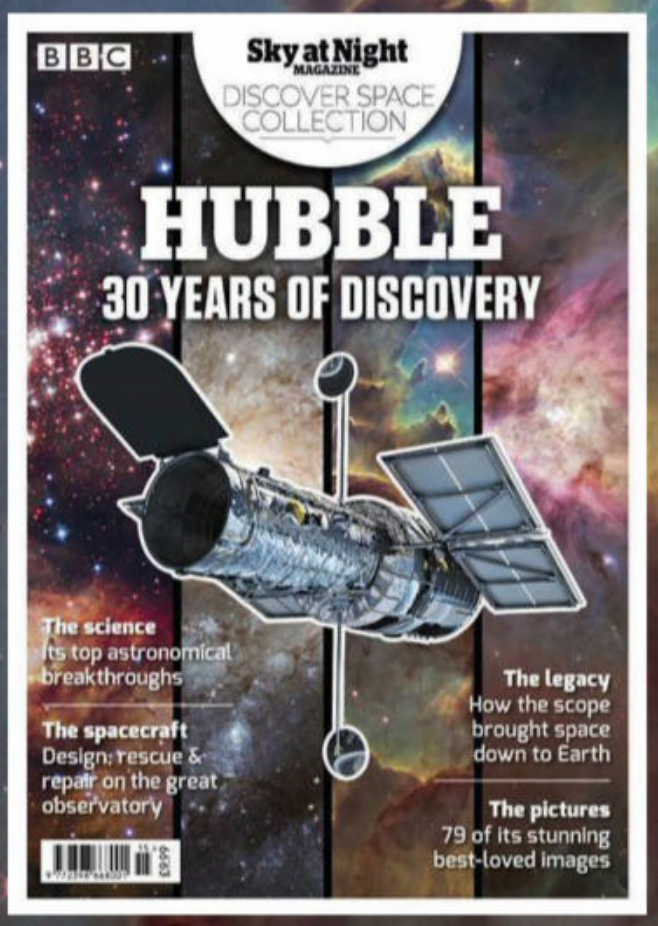
PODCASTS

ESA Explores

What's a spacewalk like? How do you exercise in orbit? This monthly podcast from ESA goes behind the scenes of life on the International Space Station.

Downloads available via all major podcast platforms

SPECIAL EDITION



FROM THE MAKERS OF BBC Sky at Night MAGAZINE

HUBBLE
30 YEARS OF DISCOVERY

ONLY £9.99 INC P&P*

For three decades, this iconic space telescope has explored the cosmos – shining a light on our planetary neighbours, discovering alien worlds, capturing the birth, life and death of stars, and delving into the darkest depths of the Universe.

This special edition from *BBC Sky at Night Magazine* reveals Hubble's story – from initial concept to the orbital repair that fixed its mirror and the risky maintenance missions. With spectacular images, you'll discover the science that it has enabled, and gain an insight into the powerful legacy that Hubble has given to people all over the world.

PLUS subscribers to *BBC Sky at Night Magazine* receive FREE UK delivery on this special edition.

NASA, ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

ORDER YOUR COPY TODAY

www.buysubscriptions.com/Hubble

Alternatively call 03330 162138† and quote 'Hubble Anniversary Print 1'

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8am–6pm and Sat 9am–1pm.

*Subscribers to *BBC Sky at Night Magazine* receive FREE UK POSTAGE on this special edition. Prices including postage are: £11.49 for all UK non-subscribers, £12.99 for Europe and £13.49 for the Rest of World.

All orders are subject to availability. Please allow up to 21 days for delivery. Please note your copy will be dispatched when available from 19 March 2020

FIELD OF VIEW

Is there anyone out there?

It's 60 years since a radio telescope was first used to search for alien life. Will a new generation of technology help us make contact with extraterrestrials?

A former lecturer in astronomy at the University of South Wales, **Martin Griffiths** is the director of the Brecon Beacons Observatory and is a science presenter for Dark Sky Wales

The year 2020 will mark the 60th anniversary of the first scientific search for life beyond the Solar System. Between April and June 1960, Frank Drake used the Green Bank Radio Telescope in Virginia to search two stars, Tau (τ) Ceti and Epsilon (ε) Eridani in an attempt to catch any intelligent signals emanating from potential planets around them. He had no success, but 'Project Ozma' started a long running search that has captured the imaginations of millions.

Life in the Universe is a concept that has been long debated. The technological progress of the last century has given us the requisite tools to enable us to look for intelligent signals from space, but the search may be a long endeavour. As Seth Shostak, senior astronomer for the SETI Institute, has said, "The search for intelligence has barely begun, and the search could take generations".

SETI – as the search for extraterrestrial intelligence is known – has many times been likened to the great voyages of exploration in the past: Magellan circumnavigating the globe, Speke discovering the source of the Nile, Marco Polo and his exploits in China. We are desperate to reach out, to make our voice heard across the cosmos, even if we can only do it indirectly.

However difficult the task appears to prove the case for SETI, it is stimulating to find that a new generation of electronics have caught up with current theory to such an extent that the BETA (Billion-channel Extraterrestrial Array) constructed at Harvard University can scan all the frequencies that extraterrestrials may broadcast upon simultaneously. In addition, the BETA equipment is fairly portable and can be geared up to any radio telescope without interfering with research projects that are in progress, continuing the search regardless of the use of the telescope. A similar project called SERENDIP (Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations) relies upon the possibility of finding an extraterrestrial signal from a piggybacked receiver.

Despite the long odds on finding life elsewhere in our Galaxy of 100 billion stars, the scientists involved in such tasks are optimistic. Missions that have identified extrasolar planets only give more impetus to the quest, while public awareness of SETI remains high, keeping the search at the forefront of human imagination.

Nevertheless, there are problems; critics have pointed out that much money is being poured into SETI research when the case for the existence of extraterrestrials is not even established. This has not held back scientists from proposing theories or generating searches, but it has to be admitted that the evidence for extraterrestrial life remains extremely promising, though currently circumstantial.

Supporters include the former director of the Ohio Project, Robert Dixon, who is correct when he states that we are barely scratching the surface, and to give up now would be pointless. Considering the money poured into military projects with little future, or bailing out the economy, the amount allocated to settling one of the greatest questions of our Universe is paltry, insulting even. SETI deserves more of a chance and its pure and applied research and potential spin-offs will never be a waste of time and effort.

MICHAEL DRIVER/FOLIO

The perfect addition to your stargazing, *BBC Sky at Night Magazine* is your practical guide to astronomy, helping you to discover the night skies, understand the Universe around us and learn exciting techniques for using your telescope.

Enjoy our Premium App experience now available from

Download on the App Store

amazon apps Available on kindle fire

GET IT ON Google play

zinio™

BBC Sky at Night MAGAZINE

A sight to behold: predicting noctilucent clouds (NLCs) may be tricky, but once you've caught a display you'll be hooked

Summer's ghosts: NOCTILUCENT CLOUDS

These high altitude clouds on the edge of space are a delight for summer stargazers, says **Stuart Atkinson**

MEINDERT VAN DER HAVEN/ISTOCK/GETTY IMAGES

Yes, you read that correctly: *Sky at Night Magazine* is encouraging you to look at clouds. But aren't clouds the mortal enemies of sky-watchers? Aren't they the Voldemort to our Harry Potter? Not these clouds, no. Although it has to be said some astronomers and sky-watchers don't consider noctilucent clouds (NLCs) to be astronomical and dismiss them as being "just clouds" or worse, "the poor man's aurora", many amateur astronomers enjoy observing and photographing them just as much as others enjoy peering through their scopes at misty spiral galaxies and glittering star clusters.

However, unlike those much-loved deep-sky objects, NLCs are not visible all the time; there is an NLC season which runs between the end of May and the start of August every year. This is part of their appeal for many sky-watchers during those long, bright summer nights: a strong display of NLCs which fills the sky gives them something to look at until the sky darkens enough for galaxies and nebulae to be visible again. Indeed, a strong NLC display can be such a stunning sight that it makes one forget all about the Andromeda Galaxy's dust lanes or the Orion Nebula's star-speckled heart.

If you're now intrigued by NLCs and wish you'd seen them before, the chances are that you already have without even knowing it.

Easy on the eye

NLCs are clouds of icy dust that form at a very high altitude on the edge of space, around 76–85km high, when temperatures and pressures in the upper atmosphere are just right. These conditions only occur during the summer months and even then not every night. NLCs only form when everything comes together. Because they are so high up NLCs are illuminated by the Sun long after it has set for us at ground level, and we see them as blue-white swirls, curls and tendrils shining in the sky. That's what their name means – 'nocti' (night) 'lucent' (shining).

Observing NLCs is easy and, best of all, completely free. You don't need any expensive telescopes, binoculars or cameras, just a pair of eyes will be fine. Having said that, a pair of binoculars will allow you to see fascinating detail and structure within an NLC display, which is invisible to the eye. You don't need to be under a pitch black sky to see them, as a good display will be so bright that it will be visible from your back garden or even your bedroom window, as long as you're facing the right direction – north.

Just as there are two recognised times of the year when conditions are better for observing the aurora, there is an 'NLC season' between the end of May and start of August. NLCs typically begin to show themselves around midnight, when the summer sky is as dark as it's going to get. However, unlike the aurora, which can now be predicted with some accuracy many days in advance thanks to the work of Sun-monitoring satellites and observatories, an NLC display can't be

TOP 5 NLC TIPS

1. Find a suitable observing location: a clear view north is key

Keep clear: select a location that doesn't have buildings or other obstacles obstructing your view

Major displays of NLCs, with activity reaching well above the horizon throughout the night, will be visible from your garden or even your bedroom window, as long as you can see the sky to the north. However, smaller displays which hug the horizon will be much harder to see if your view north is obscured by neighbouring houses, tall buildings or hills. You'll have the best view of a display if you can get to somewhere with a low, flat horizon and a clear view sweeping from west to east. And obviously the less light pollution you have, the better.

JUHKU/ISTOCK/GETTY IMAGES, DMITRIYDANILOV/ISTOCK/GETTY IMAGES, © TWITTER

TOP 5 NLC TIPS

2. Use social media and the internet: it can help you predict NLC activity

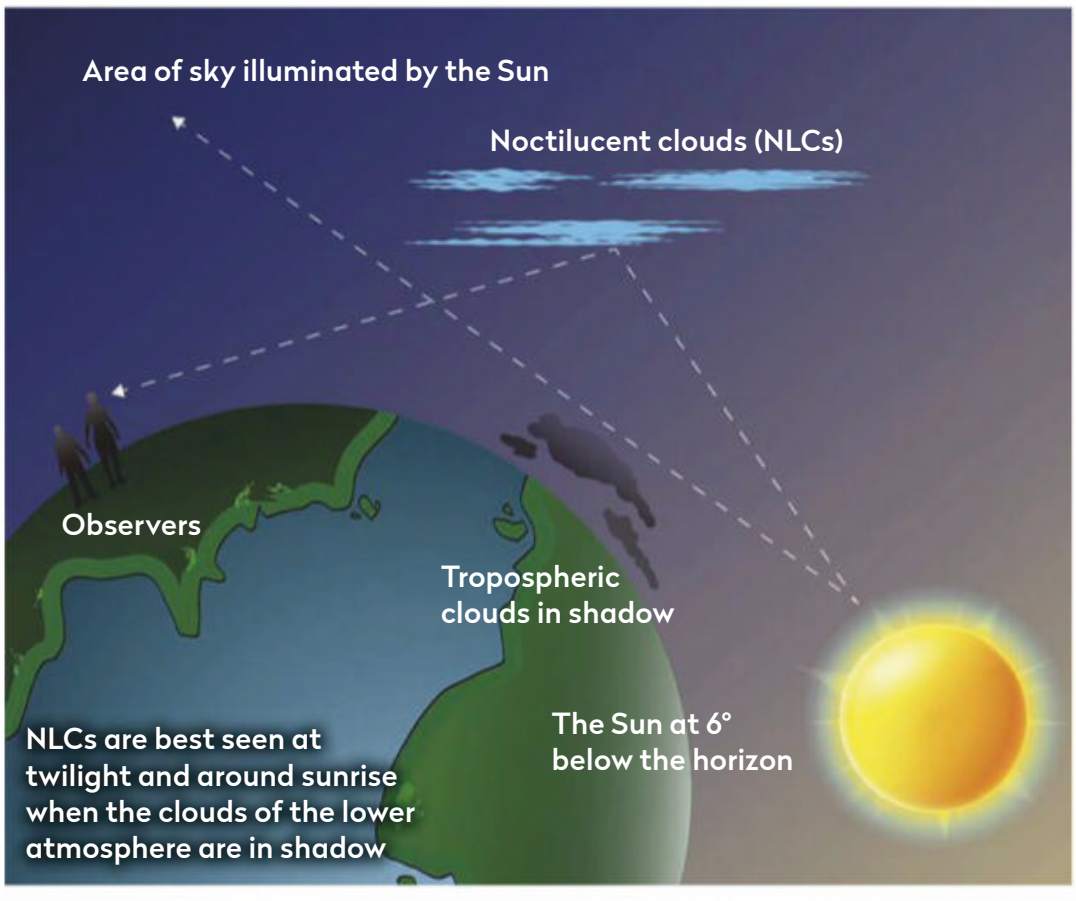
Most noctilucent cloud-watchers (NLCs) now use online resources to ensure they don't miss a display. The more experienced ones monitor specialised websites that provide information about physical conditions in the upper atmosphere, looking for signs that NLCs might be forming, such as the website of Germany's Liebniz Institute of Physics, at **bit.ly/maarsy-mesosphere**. Others keep an eye on north-facing webcams in countries further east where sunset occurs first, like those found at **bit.ly/nlc-kamera-netzwerk** to alert them when a display is visible.

Social media platforms such as Facebook and Twitter have communities of NLC-watchers who share their observations and alert members of the group when an impressive display is in progress; the bigger groups based in the UK are: **www.facebook.com/groups/AuroraUK/**, **https://twitter.com/nlcnet**, **https://twitter.com/space_clouds** and **https://twitter.com/NLCalerts** (right).

All of these online resources means that it's actually quite hard now to miss out on a big display of NLCs if you really want to see one.

predicted more than a few hours in advance, because the conditions that lead to their formation are so specific and they only exist for brief periods.

In times past, NLC-watchers had no choice but to head out on every clear summer's night in the hope that NLCs would just appear in the northern sky. More often than not they didn't, which was very frustrating. Now NLC watchers monitor satellite images and data to see if conditions in the upper atmosphere might be suitable for producing NLCs that evening. As sunset approaches we can monitor north-facing webcams in countries further to the east of us, where the Sun has already set, to give us an alert for any displays that are already in progress, which we might see later. And, of course, we use social media to communicate with fellow NLC hunters who will clang a virtual bell in cyberspace's town square if a display is happening.



Plan ahead

So, if you want to see these mysterious clouds for yourself, how do you go about hunting NLCs? First of all you need to stay awake. There's no point going out until around 11.30pm because the sky just won't be dark enough for NLCs to be visible, even if they're there. Then, if the sky is clear, wrap up warmly, grab your binoculars and camera if you have them and head out. If you have a clear view to the north from your garden you won't need to go any further than that, but as is the case with observing the aurora, the lower, flatter and less obscured your northern horizon is, the better your chances will be of seeing something. ▸

▸ And if you're not sure which direction is north, here are two tips for you: look to the right of where the sky is still quite bright from the late sunset or look for the bright star Capella shining just above the horizon. If you find Capella you're looking in the right direction.

And then? Then you wait. The NLCs will either appear, or they won't.

Lucky streaks

If NLCs do appear, the first you'll see of them will probably be what look like a couple of streaks of gold-white cloud low in the northern sky, like distant vapour trails. Then it's time to cross your fingers.

If you're unlucky that will be all you'll see and they will drop beneath the horizon out of sight. You'll need to decide then if you're going to stay out and see if they come back, or head home to bed. As is the case with watching a meteor shower, stay out as long as you can; it's not uncommon for a display to fade away to nothing and then return and be bright and beautiful.

But if you're lucky, as the sky darkens those streaks will get brighter and higher, and will become more blue-white than gold. You might see some feathery patches of blue-white. If you can see those, you're seeing NLCs.

Then what have you to look forward to? Those lonely few strands of golden white will bloom into an arch or swirls of electric blue, extending slowly to the east and west. As the display increases in height and brightness it will develop other structures and forms. You'll see loops, curls and twirls of NLCs across the northern sky. In places you'll also see flat, feathered plates of NLCs marked with a distinctive cross-hatch pattern, like mashed potato decorated with a fork.

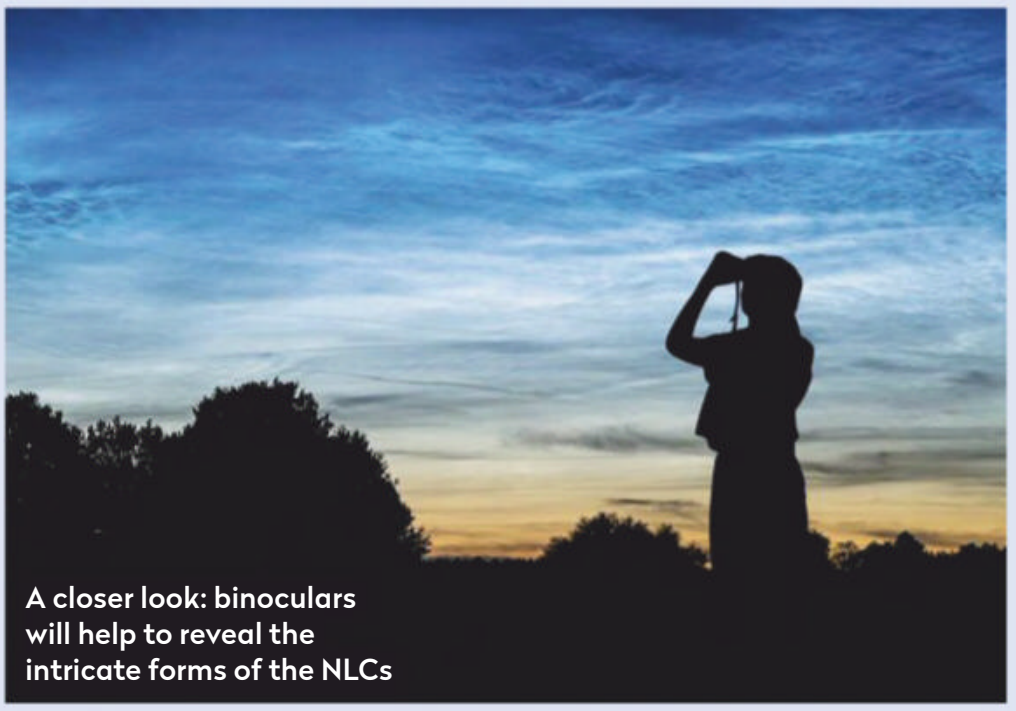
You'll also see movement too, but you won't see the NLCs fluttering and swaying like the aurora. Instead they move slowly over a timescale of minutes instead of seconds. Curls will uncurl or curl tighter; tendrils and streamers will grow longer, or ravel up again; and cross-hatching will spread out in one place and grow more vivid in another. You'll notice these changes with the naked eye, but they'll be more obvious with binoculars.

Sometimes an NLC display develops into a storm that covers half the sky. If you find yourself out under one of those you are in for a very special night indeed – and a long one, because such a display can still be

JA'CRISPY/ISTOCK/GETTY IMAGES, JUHKU/ISTOCK/GETTY IMAGES, MOONSHOT11/ISTOCK/GETTY IMAGES, LPHOTO7/ISTOCK/GETTY IMAGES

TOP 5 NLC TIPS

3. Use binoculars: they'll show subtle details and colours



A closer look: binoculars will help to reveal the intricate forms of the NLCs

NLC displays are beautiful to the naked eye but they look even better through a pair of binoculars. The same binoculars you use to look at the Pleiades, M31, and the phases of the Moon will give you very clear views of the subtle shapes, structures and forms NLCs can take, and will enhance their lovely colours too. They will also help you see how bright NLC displays change shape through the night. And they are extremely useful for helping you spot the first faint signs of a display before it becomes obvious to the naked eye.

TOP 5 NLC TIPS

4. Take photos with a phone camera: NLCs are bright enough

You don't need an expensive or complicated camera to photograph NLCs; many phones now have cameras that are more than good enough to take lovely photographs of bright displays. Hold your phone as steady as possible, make sure that you include some foreground objects in your pictures for scale, and try your phone camera's night mode setting if it has one. If you can, frame your photos so the NLCs are reflected in a river or a lake, or have trees or buildings silhouetted against them. If a display is too big to fit on one single photo, try your camera's panorama mode.

Silver screen: take a picture on your phone with the NLCs reflected in water or framed with trees

Stuart Atkinson is an amateur astronomer and author of nine books with more than 30 years' experience of observing NLCs

going strong and filling the sky as the eastern horizon begins to brighten with the approach of dawn.

During an NLC storm all bets are off. All you can do is stand there, open-mouthed, entranced by what you're seeing as the sky from east to west, and overhead, is painted with beautiful streamers, billows, whirls and swirls of electric blue light, bright enough to cast shadows. You simply won't know which way to look, in case you miss something happening in another direction. Scanning the display with your binoculars you'll shake your head in wonder at what you're seeing – elegant twirls of lavender and blue wrapping around each other like snakes; spirals and curls of silver and white glowing like the filaments of light bulbs; veils of gold spreading out from one side of the sky to the other. There's simply nothing else like it in astronomy.

Eventually though you will have to go home, either because the sky is so bright that the NLCs are being washed from it or because you can't keep your eyes open any longer – but what memories you'll have.

Perhaps NLC aren't an astronomical phenomenon, strictly speaking, but they are a welcome sight in the summer sky for many astronomers and sky-watchers starved of views of the stars, galaxies, nebulae and clusters they look at during the other seasons of the year. And they are gorgeous.

▸ **Turn to page 43 for more on observing NLCs**

TOP 5 NLC TIPS

5. Use a DSLR camera: take beautiful long exposures

A modern DSLR camera will take beautiful photos of NLCs. Fit it with a wide-angle lens, set it to manual so you can take long exposures and mount it on a tripod to keep it steady. With the aperture as wide as possible, set the ISO to 800 and take a few test exposures of several seconds. If the NLCs are burned out and no detail is visible, reduce the ISO and the exposure time until the photos show the display properly. Use a longer lens and higher ISO to record fine structure within NLCs. You could even try an NLC selfie, showing you silhouetted against them.

Put yourself in the picture: try a silhouette effect with your DSLR

Lines of enquiry: a composite of long-exposure images shows Starlink satellites passing over northwest London on 23 April

Under a STARLINK SKY

Megaconstellations of satellites could soon be lighting up the night sky. **Ezzy Pearson** looks at the impact on astronomy

On the night of 24 May 2019, astronomers looked up to see a chain of bright lights moving across the darkness. While the flash of planes and satellites are familiar sights in the night sky, no one had ever seen so many, so bright and so close together.

As images and videos of the strange sight made their way around social media, the culprit soon became apparent – 60 satellites released by spaceflight company SpaceX as part of its Starlink project. And this was just the first batch of many.

Starlink is a megaconstellation – a network of satellites in low-Earth orbit. Its goal is to supply cheap internet access around the entire globe, particularly in rural and remote areas beyond the reach of traditional connections. The 'mega' part of the name is certainly earned. When finished, Starlink will consist of over 12,000 satellites. With other companies, including Amazon, UK-based ▸

STEPHEN CHUNG/ALAMY STOCK PHOTO

▸ OneWeb and several Chinese enterprises all aiming to launch similar constellations, the sky could soon be filled with tens of thousands of these satellites.

The initial brightness of the Starlink satellites surprised even SpaceX, though CEO Elon Musk was quick to reassure the public on Twitter. "There are already 4,900 satellites in orbit, which people notice ~0% of the time. Starlink won't be seen by anyone unless looking very carefully & will have ~0% impact on advancements in astronomy," he said.

Light debate

The super bright phase, he asserted, would just be during the early stages of the satellite's deployment. When they reached their final altitude and orientation they'd be much dimmer. Over time, the satellites faded to around mag. +5.5 – faint, but still visible to the naked eye at a dark-sky site and bright enough to ruin any professional observation they happened to drift through.

"I felt Elon Musk's comments were the wrong way to characterise this," says John McDowell, from the Harvard–Smithsonian Center for Astrophysics, who has created a simulation of what the completed megaconstellation will look like using magnitude measurements taken by amateur satellite observing community, SeeSat. "Most of those 4,900 satellites are in higher orbits, or much smaller and so not contributing to the light pollution problem. These [Starlink] satellites are large and low – around 550km up. Both those things together mean they're bright. Prior to the first Starlink launch there were about 400 large, low satellites: 12,000 compared to 400 is quite a big increase."

▲ Bright ideas: Amazon founder Jeff Bezos has plans to compete with SpaceX for space internet supremacy with his own satellite project

CHUCK BURGER/ALAMY LIVE NEWS, ZDENEK BARDON/WWW.BARDON.CZ, GENE BLEVINS/ZUMA WIRE/ALAMY LIVE NEWS, GRAPHS BY PAUL WOOTTON/DATA: JOHN MCDOWELL

No more star trails?

Astrophotographers could struggle with taking pictures of the night sky

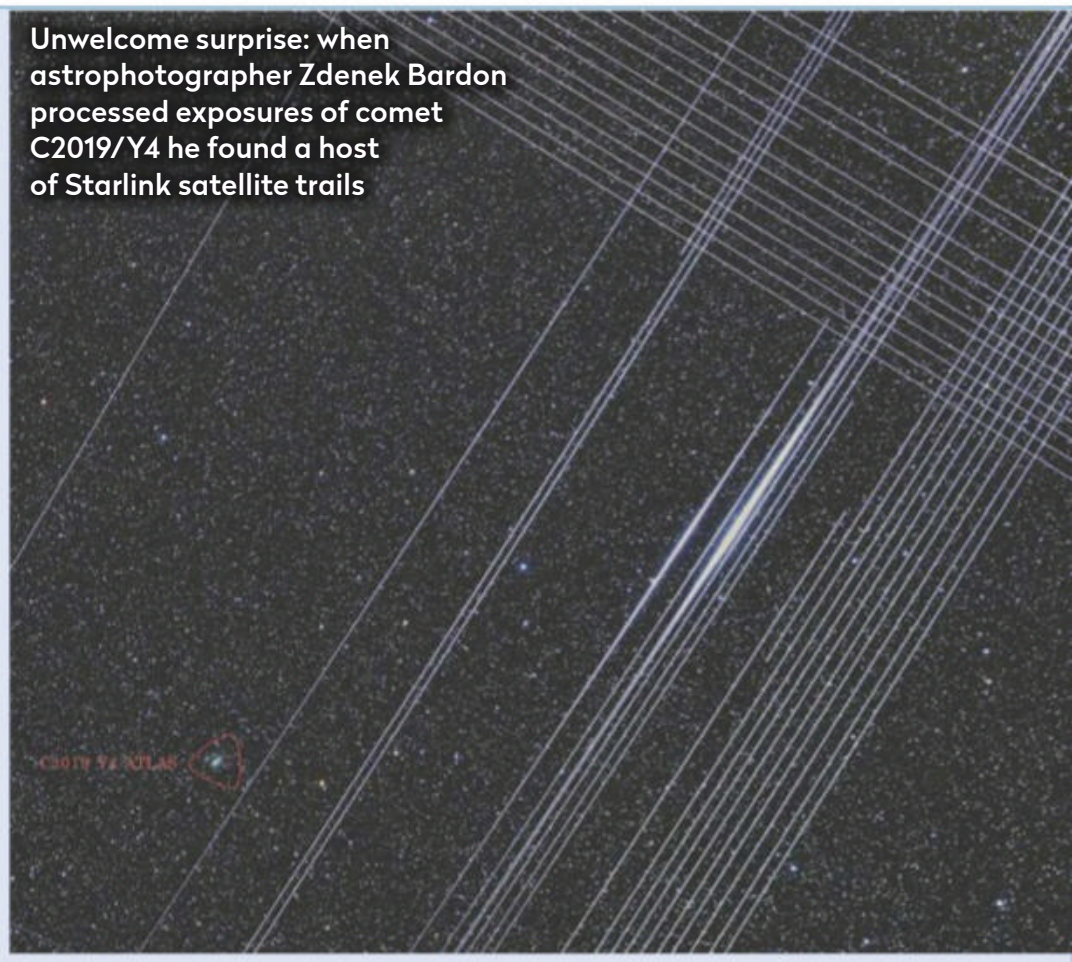
Amateur stargazers were one of the first groups to realise the impact of Starlink satellites on views of the night sky.

"The first day of the launch I got loads of messages asking what was going on," says astrophotographer Alyn Wallace. "They'd just seen the first train of satellites coming over the UK and were trying to work out what they'd just seen."

For most visual observers, the effects shouldn't be too bad. The satellites are currently only visible to the naked eye from dark-sky sites, and SpaceX seems committed to reducing their brightness below even that. Meanwhile, for those looking through a telescope, a satellite drifting through the eyepiece should be a rare and momentary annoyance.

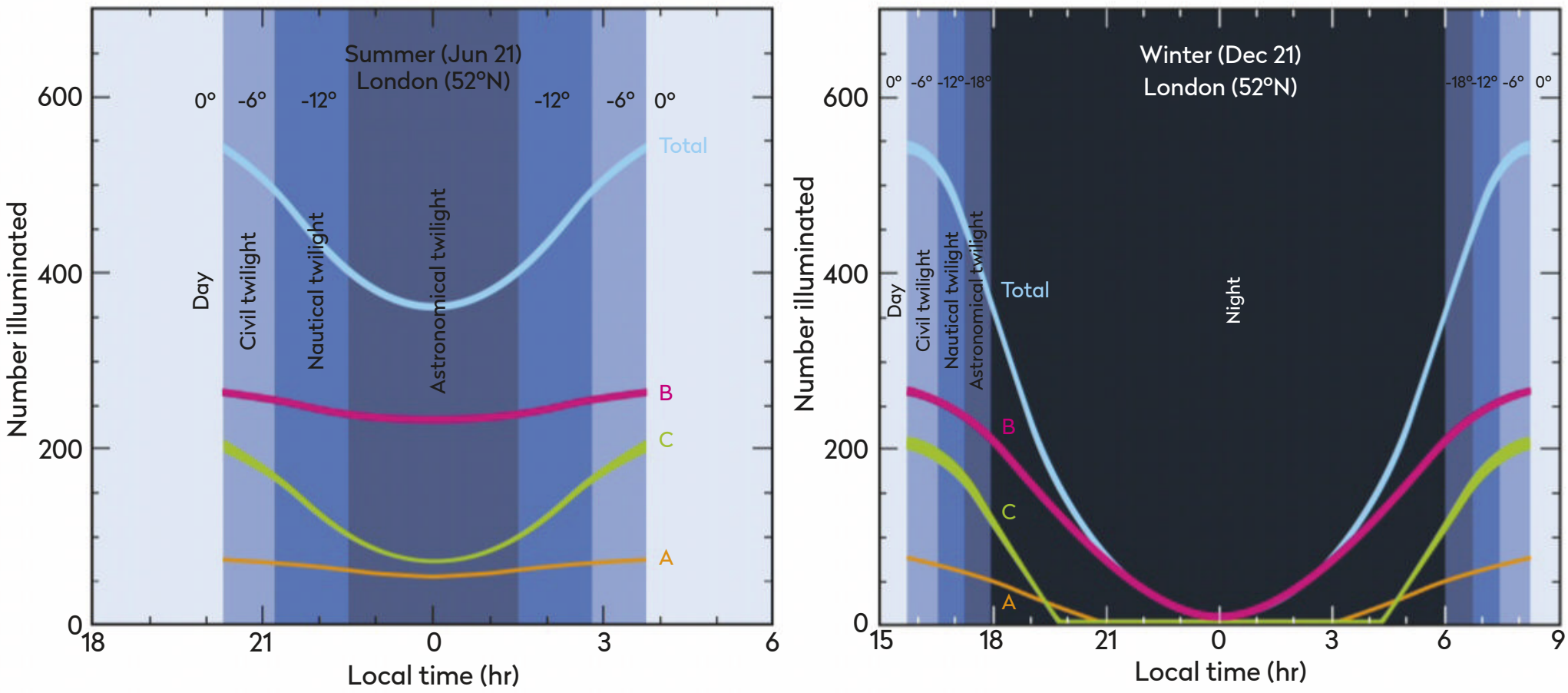
The community which will be worst hit, however, are astrophotographers, especially those taking long exposure, wide-field shots such as star trails. Amateurs could even be more affected than professionals, lacking the precise orbit information and resources to remove any trails available to scientists.

"It's going to ruin images," says Wallace. "People are going to have to throw data away. It's not something you can escape from. You can always escape light pollution and go to a dark place, but with Starlink it doesn't matter where you are. You'll always look up and see a sky full of satellites."



Unwelcome surprise: when astrophotographer Zdenek Bardon processed exposures of comet C2019/Y4 he found a host of Starlink satellite trails

Joining the dots: they may appear insignificant to the naked eye, but SpaceX's Starlink will become a global network of over 12,000 satellites



▲ **These graphs show how many Starlink satellites will be illuminated (and potentially visible) in the UK sky during the summer (left) and winter (right) once the constellation is fully deployed. Line A indicates mid-altitude satellites (550km), while line B shows those at high altitude (~1,200km) and line C at low altitude (~340km). The Total line reveals the sum of all three groups. The background shading highlights when the sky is in day, night or twilight**

McDowell used his simulations to mimic what the sky would look like at various different points on the globe, analysing how it would change the sky for both professional observatories and the average person looking up from a dark-sky site.

"The question is how many satellites can see the Sun when you can't. If you can see the Sun it's the middle of the day and you're probably not doing astronomy, and if the Sun is below the horizon the satellites will be dark and you're probably not that bothered," says McDowell. "The bad thing is when the Sun is a bit below the horizon so that the ground where you are is dark, but the altitude where the satellite is in space isn't."

Though satellites nearest to the horizon were most affected, more were seen at latitudes under the extreme top and bottom of their orbits, where the satellites linger longest. This latitude happens to be at 53° north and south – landing it right in the middle of the UK.

"If you're in the UK in the north in summer when the Sun never really sets then the satellites are always going to be illuminated," says McDowell. "You're going to see a lot of these things all summer long and it's going to be noticeable."

While this isn't welcome news for those observing from the UK, many professional telescopes are located closer to the equator. For those with a small field of view, the chances of a satellite drifting through any given frame are reassuringly low.

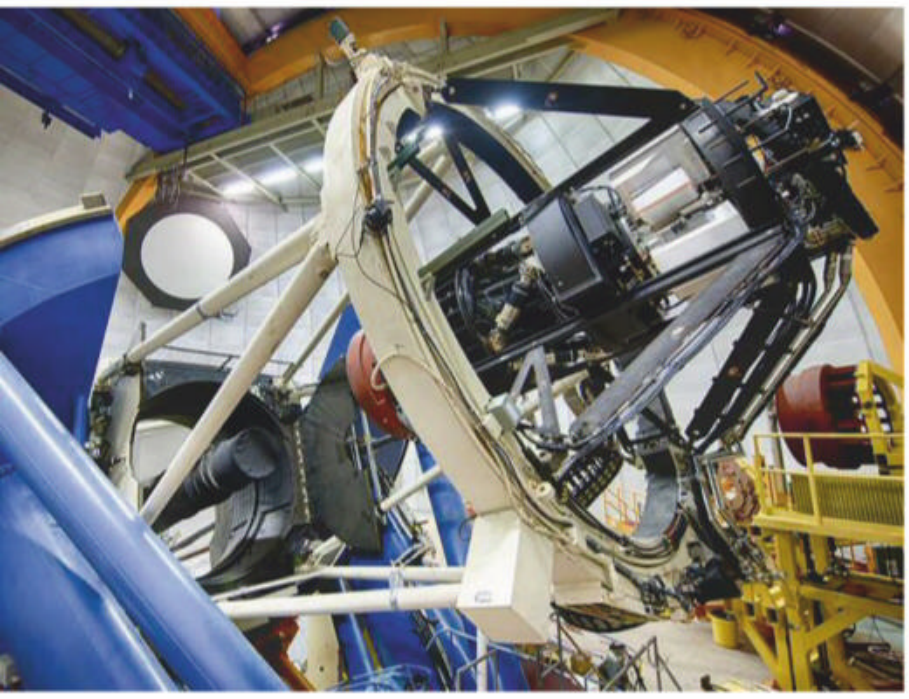
"There's a lot of projects that require some (relatively achievable) mitigation to avoid the satellites. This amounts to an increase in observing time, which is expensive, but it's not the end of astronomy," says McDowell.

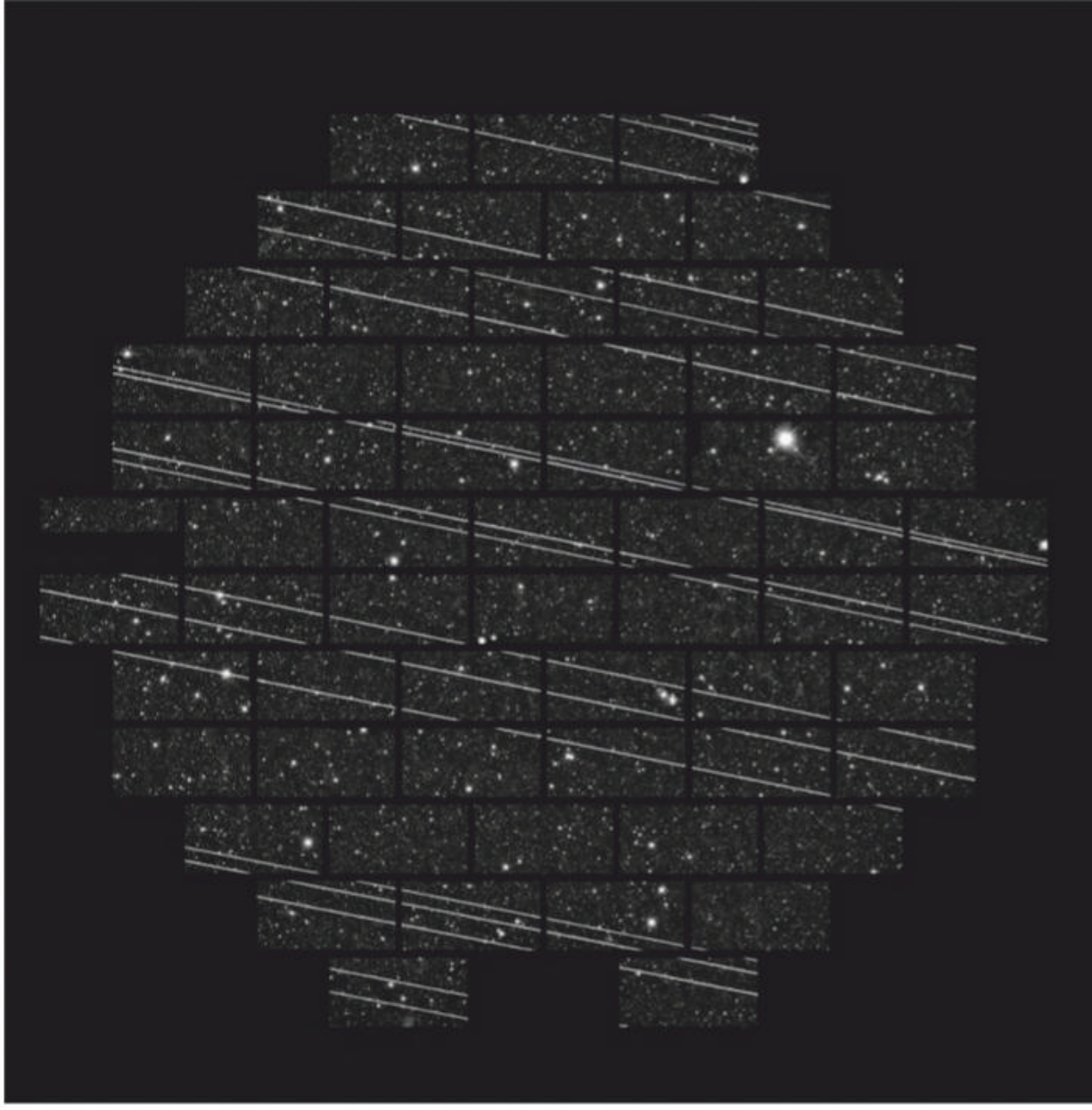
Large-scale issues

'A lot', however, is not all. One major telescope that will be severely affected is the Vera Rubin Observatory (VRO), previously known as the Large Synoptic Survey Telescope) being built in Chile.

"The observatory will survey the entire southern sky 1,000 times in six wavebands," says Tony Tyson, chief scientist for the VRO. "It's a 10-year survey of the entire southern sky and it has an uncommonly wide field of view. You could fit 40 Moons inside a single snapshot."

Such a wide field means that the telescope is the perfect machine for picking up satellite trails. Previously, this hadn't mattered as most satellites are much dimmer. ▸





▸ "Something that bright saturates our detectors. It's not something we can easily remove from the data because it leaves a lot of artefacts behind in the image," says Tyson.

While it could be possible to plan out when a satellite will be going by and halt observations until it passed, the VRO takes images at such a rate that even a few seconds of delay could increase the survey time by several years.

As things stand, once the full constellation is deployed as many as 30 per cent of all VRO images could contain a satellite trail. That is, of course, unless SpaceX changes its plans. When it became apparent just how bright the satellites were – and how upset the public was about the potential of a sky filled with them – the company began working with astronomical institutions, including the VRO, to see what could be done. "We've been working with them on several different ideas," says Tyson. "The first one, called DarkSat, launched in March. They've blackened areas at the bottom of the spacecraft bus that looked bright in imaging. Meanwhile another solution SpaceX is working on is to create a sunshade that shades the bottom of the satellite, so it doesn't reflect light, called VisorSat."

While VisorSat has yet to be launched at the time of writing, early observations of Darksat show its brightness has dropped by as much as a magnitude, taking it below naked-eye visibility. Now the question becomes 'Will this be dark enough?'

Establishing that, however, is a challenge, says Robert Massey of the Royal Astronomical Society (RAS). "Part of the problem is that we haven't really, as a community, accepted what the maximum brightness of a satellite is," he explains. "Is it naked-eye visibility, mag. +6.0? Or fainter than that? Can we tolerate something brighter? Those discussions need to be had."

Finding common ground

To help those discussions along, the RAS ran a conference in January, bringing together members of the professional and amateur astronomical communities with representatives of SpaceX and OneWeb. The goal of the meeting wasn't to stop companies from their quest to bring internet access to everyone, but to ensure they were doing so without exacting a price the world wasn't willing to pay.

"It's hard for astronomers to argue against global internet," says Massey, "but my particular view is that there is a shared ownership of the sky. There should be public input into that."

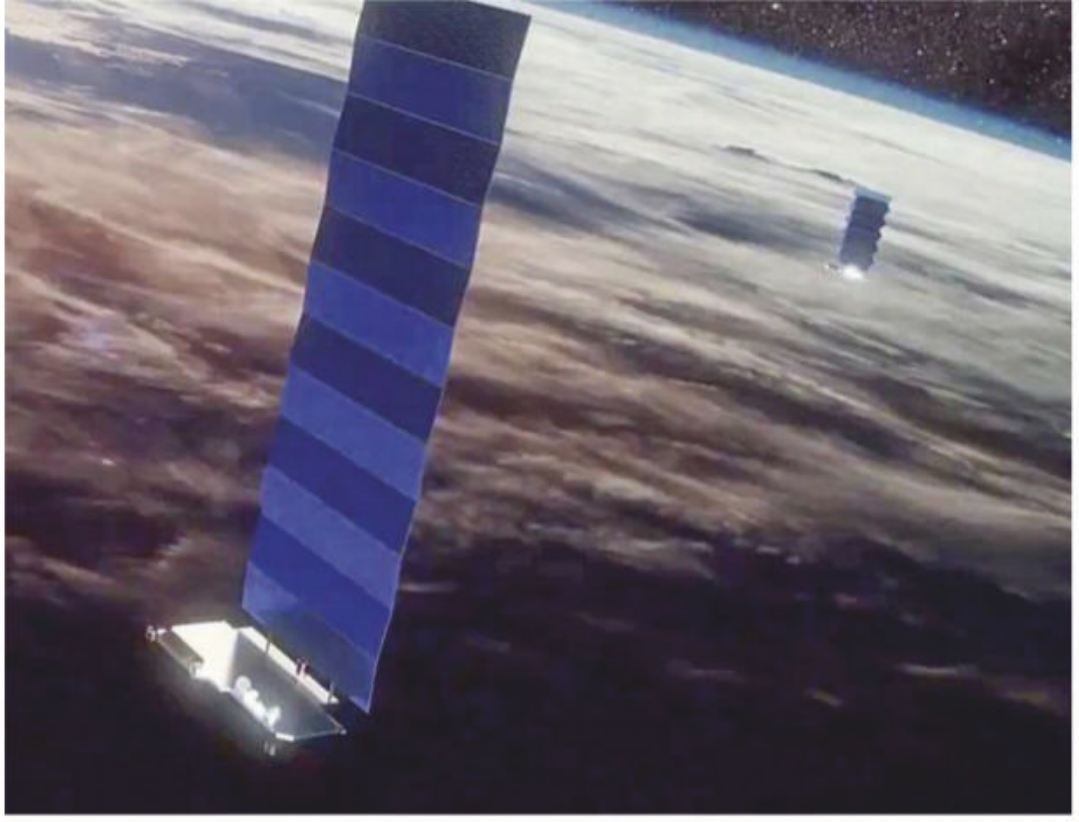
The problem with shared ownership, however, is that there is no one organisation governing our view of the heavens.

"You can develop guidelines, but how do you make them enforceable?" says Massey. "That requires an international treaty and that may take a very long time."

Currently, the only global governance comes from the United Nations Outer Space Treaty, a list of guidelines agreeing what it means to be a good citizen in space. It's then up to each individual country to make their own laws, usually using the Treaty as a template. While there is little compelling nations to pick up these guidelines, a similar approach has been remarkably effective in tackling the problem of space junk.

▲ Big issue: some large observatories have been picking up Starlink satellites too. An image (above) from CTIO (Cerro Tololo Inter-American Observatory), taken in Chile by the dark energy camera DECam (left, below) mounted on the Blanco 4m telescope (left, above) reveals 19 satellite trails

Dr Ezzy Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

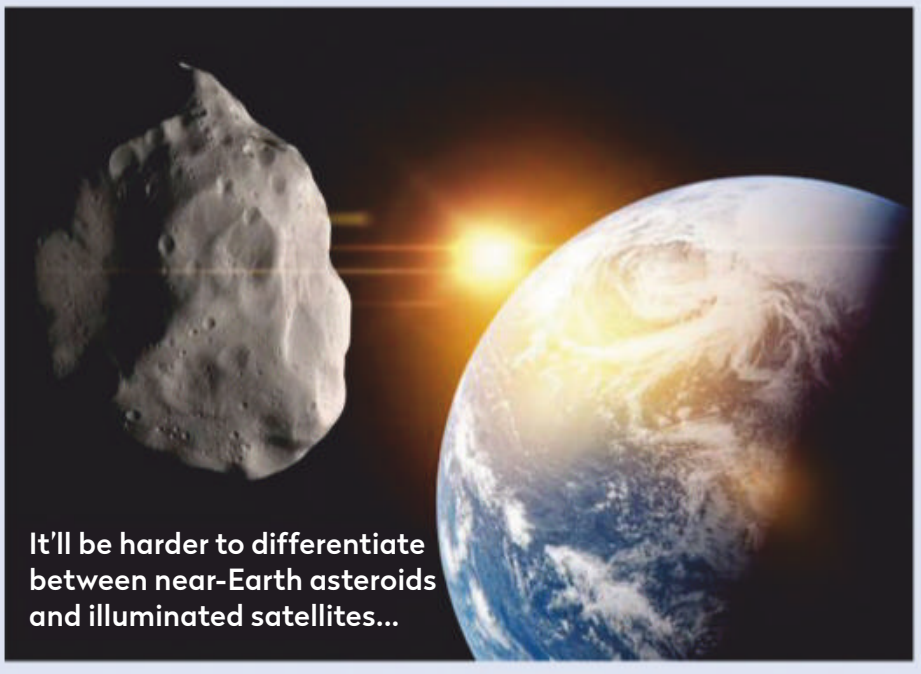


▲ Could external regulation help to ensure that projects like Starlink (above) are in the best interests of everyone with a view of the sky?

We approached SpaceX for a comment for this article, but did not receive a response. However, everyone we spoke to agreed the company is at least interested in being a 'good space citizen' and fixing the problem. One thing they are not doing, however, is slowing down the launches of their Starlink satellites. Over 300 satellites are already in orbit, only one of which has had any kind of measures to mitigate its brightness.

"Besides wanting to get revenue from the system as soon as possible, the licence to launch the first 1,584 satellites of the constellation is only for five years, so SpaceX is under some pressure to continuously launch, despite all these discussions," says Massey.

"History confirms that a reliance on the benevolence of the business world has not been a great strategy for the public," says McDowell. "While it's great that SpaceX and others are taking this seriously and trying to fix the problem, I think we need some level of regulation that's not so onerous that it inhibits the development of space. There should be a global governance of a resource that's been important to humanity for millennia."



It'll be harder to differentiate between near-Earth asteroids and illuminated satellites...

...and the already cluttered low Earth orbit will need to be navigated carefully

A sky for everyone

The heavens are a global resource, where everyone has an investment

For astronomers, the reasons for keeping satellite light pollution down are obvious, but they are not the only one with an investment in the night sky.

"There are cultures around the world who may not be heavily involved with space, but who live in less urbanised environments and have a strong tradition associated with the night sky," says John McDowell. "These people might be put out if the night sky was changed suddenly without them being consulted."

One major scientific enterprise which could suffer is the search for near-Earth objects, as the conditions which are best for illuminating space rocks are the same for illuminating satellites. With thousands of satellites moving across the sky, it will be difficult for surveys to pick out the motions of an asteroid, making it all too easy for a potentially dangerous object to slip through without detection.

Then there is the question of space junk. Low-Earth orbit is home to thousands of satellites and is already getting cluttered.

"With 10,000 satellites, they have to make sure they have decent traffic control," says Robert Massey from the RAS. SpaceX has already come under question over this, when on 2 September 2019, ESA had to divert one of its satellites to avoid a collision. "It's important that SpaceX's systems can be deorbited easily and reliably. Even a small failure rate will still amount to a reasonable number that aren't under control."

The potential benefits from the system are undeniable. Megaconstellations will supply internet to people who could never gain it through conventional means. "Even if the final decision is, 'Yeah, cheap internet is so important we'll throw the night sky overboard', it should be a matter for the global community to review," says McDowell.

INTRODUCTORY SUBSCRIPTION OFFER

BBC

Science Focus

HALF PRICE

ALL THE LATEST IDEAS, DISCOVERIES AND BIG QUESTIONS ANSWERED...

Get a whole year of *BBC Science Focus Magazine* delivered direct to your door for half price when you subscribe!

The essential guide to the most important ideas in science and technology today. Every issue of *BBC Science Focus Magazine* will help you get to grips with the mind-blowing discoveries and breakthroughs that matter.

Subscribe today to *BBC Science Focus Magazine* for HALF PRICE!

Visit: buysubscriptions.com/SFHA347

Phone: 03330 162 113+ (please quote SFHA347)

+UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8 am – 6pm and Sat 9am – 1pm. If calling from overseas please call +44 1604 973721.Offer ends 31 May 2020. Half price offer is only available to UK residents paying by Direct Debit. Subscriptions will start with the next available issue.

BBC Sky at Night MAGAZINE

16-PAGE STARGAZING GUIDE

The Sky Guide

JUNE 2020

THE MOON MEETS VENUS

Observe the lunar occultation of Venus on 19 June

NOCTILUCENT CLOUD SEASON

Spot 'night-shining' clouds in the mesophere

IN GANYMEDE'S SHADOW

Discover when to watch the transit of Jupiter's largest moon

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 50

Also on view this month...

- Minor planet 7 Iris reaches opposition
- Discover the Moon's Mare Undarum
- Begin our binocular tour from star Zubenelgenubi

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

JUNE HIGHLIGHTS

Your guide to the night sky this month

◀ All month

June and July are the best months for trying to spot elusive noctilucent clouds (NLCs). Turn to page 43 for more information.

Wednesday 3

Venus reaches inferior conjunction but is sadly too close to the Sun for safe viewing. After today this iconic planet returns to the morning sky.

◀ Saturday 6

Our Moonwatch target (see page 48), Mare Undarum is well positioned on tonight's almost full Moon. Also look out for the Moon illusion just after it rises shortly before midnight BST. The low, fuller phases of the Moon can look artificially huge due to this effect.

Tuesday 9

After midnight on 8 June, the planets Jupiter and Saturn appear close to the Moon. Jupiter is shining at mag. –2.5, Saturn at +0.6. The waning gibbous Moon will appear 87%-lit. View around 01:00 BST (00:00 UT) on 9 June, low in the southeast.

Tuesday ▶ 16

Mag. –4.2 Venus reaches its 5%-waxing phase.

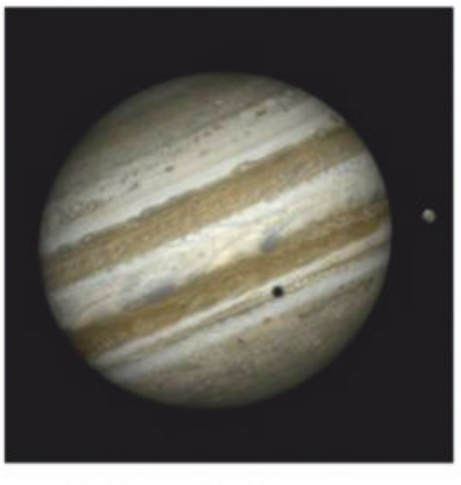
The weak June Lyrids meteor shower reaches its peak today with a ZHR (zenithal hourly rate) of 3 meteors per hour.

Wednesday 24

Fading comet C/2017 T2 PanStarrs is close to M106 this evening, passing less than a degree south-southwest of the mag. +8.3 galaxy into the early hours of 25 June.

Thursday ▶ 25

A telescopic view of Jupiter will show Ganymede's shadow crossing its disc from 23:35 BST (22:35 UT). The shadow transit is visible until 02:50 BST (01:50 UT) on 26 June. Ganymede starts to transit as the shadow reaches the central meridian around 01:15 BST (00:15 UT) on 26 June.



Saturday 27

The weak June Bootid meteor shower reaches peak activity with a ZHR (zenithal hourly rate) of 5 meteors per hour.

Mag. –4.4 Venus reaches 15% phase in the morning sky.

PETE LAWRENCE X 7

18+

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

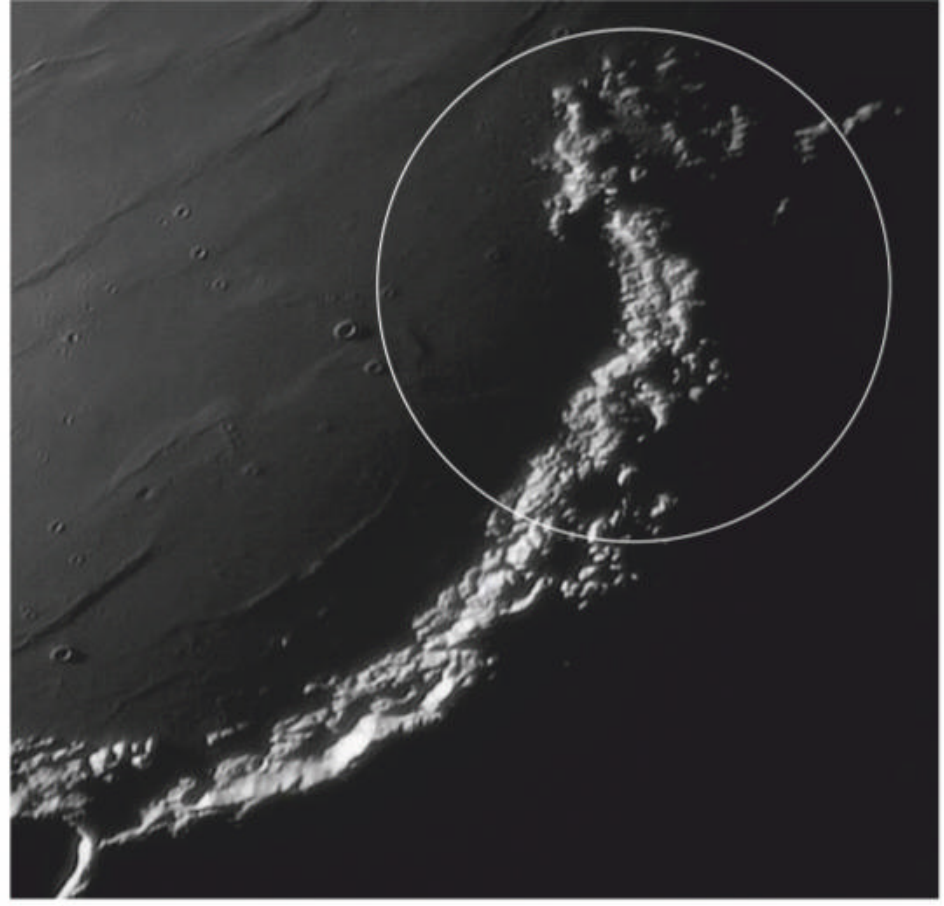
18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

We have everything for all of your needs. Just open https://avxlive.icu



Tuesday ▶

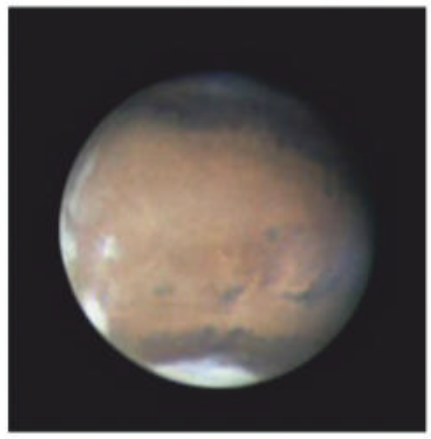
2 Look out for the clair-obscur effect called Cassini's Moon Maiden this evening. This light and shadow play at the southern end of the Jura mountain range is supposed to resemble a girl with flowing hair looking across the bay. Best seen in an inverted (south-up) view.

Thursday

4 Mercury reaches greatest eastern elongation, appearing separated from the Sun by 23.6° in the evening sky. Try and catch it around 22:30 BST (21:30 UT) low above the northwest horizon.

◀ Friday

5 A penumbral lunar eclipse occurs today but the circumstances from the UK aren't promising as it's only the end of this weak eclipse which will be visible as the Moon rises into a bright evening sky. The eclipse ends at 22:04 BST (21:04 UT). Moonrise is around 21:30 BST (20:30 UT).



◀ Friday

12 This morning it's the turn of Mars to be visited by the now 51%-lit, last quarter Moon. Catch the pair in the early hours low in the east-southeast. Mars is currently shining at mag. –0.2.

Saturday

13 Not an easy spot at this time of year, but if you have clear skies in the early hours of 13 June, using binoculars see if you can see mag. +7.9 Neptune 1.7° to the north of mag. –0.2 Mars.

Friday

19 Morning planet Venus will be occulted by a 3%-lit waning crescent Moon around 08:40 BST (07:40 UT) under daylight skies. Turn to page 42 for further information.

Saturday

20 The Sun reaches its most northerly point in the sky at 22:43 BST (21:43 UT) marking the instant in time known as the Northern Hemisphere's summer solstice.

Monday

22 Mag. –4.3 Venus reaches its waxing 10% phase.

Sunday

28 Asteroid 7 Iris comes to opposition in Sagittarius at mag. +8.8. Turn to page 49 to find out more about it.

Family stargazing

June is a challenging time for astronomy because night is constrained to a few short hours centred on 01:00 BST. Although waiting for darkness may be impractical for young observers, there are always noctilucent clouds (NLCs) to keep watch for (see page 43). If present these can be seen 90-120 minutes after sunset low above the northwest horizon, or a similar time before sunrise low above the northeast horizon. Possibly best suited to weekend viewing, if you have a home view either northwest or northeast with a clear horizon, watches can take place from home. **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

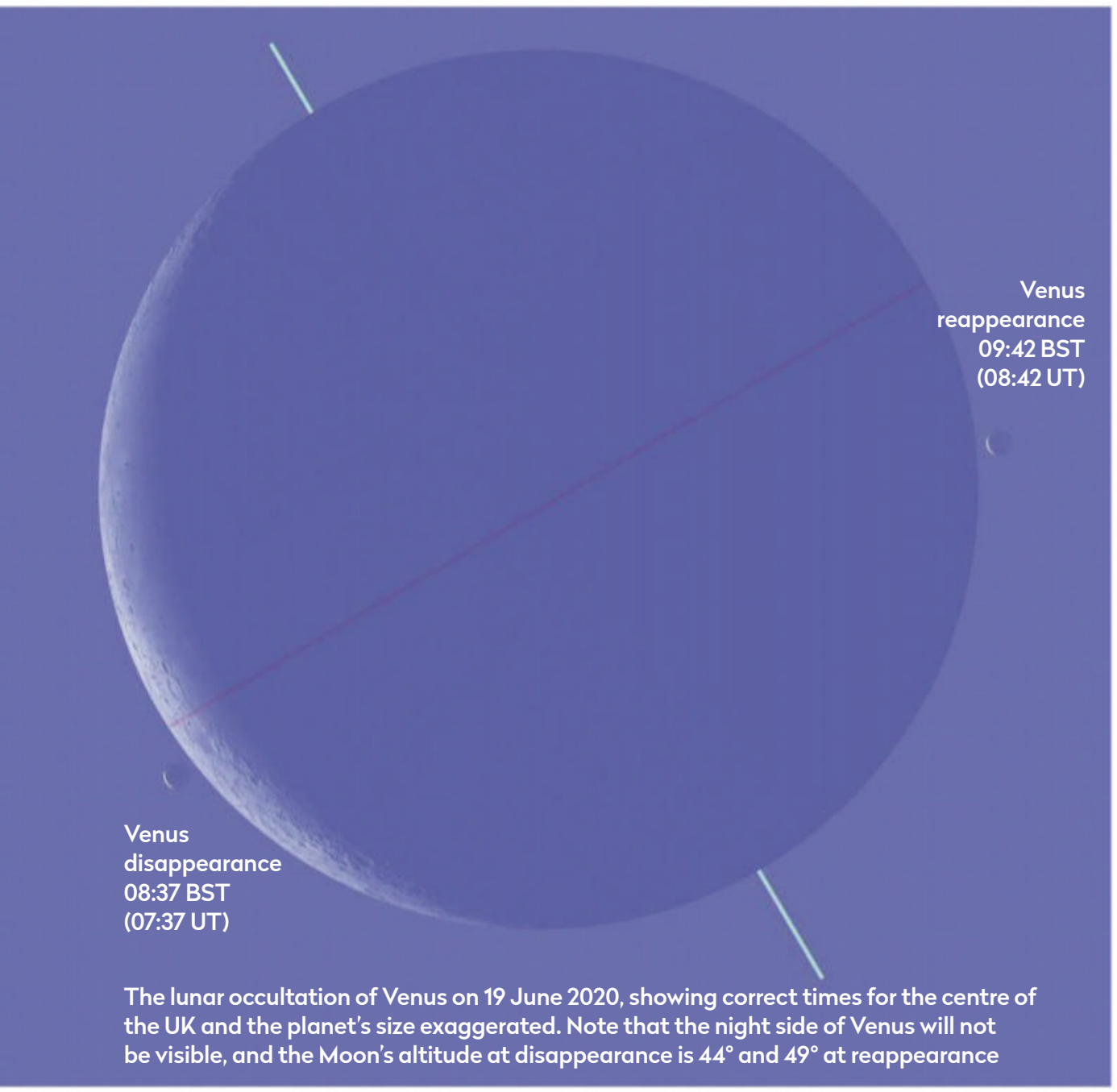
Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The three top sights to observe or image this month



The lunar occultation of Venus on 19 June 2020, showing correct times for the centre of the UK and the planet's size exaggerated. Note that the night side of Venus will not be visible, and the Moon's altitude at disappearance is 44° and 49° at reappearance

DON'T MISS

Lunar occultation OF VENUS

BEST TIME TO SEE: 19 June from 08:20 BST (07:20 UT) until 10:00 BST (09:00 UT)

Venus has been a dramatic object in the evening sky so far for all of 2020, but this month it's notable because of its absence. The reason for this is that it is passing around a part of its orbit which is closest to Earth. As it does so it lines up with the Sun in the sky to reach a position known as inferior conjunction; inferior simply indicating that Venus is between Earth and the Sun.

On rare occasions Venus appears to pass in front of the Sun at inferior conjunction. Known as a transit of Venus, this won't happen again until 2117. For many inferior conjunctions it is possible with care, to keep track of Venus as it passes close to the Sun. On 3 June it appears to pass half-a-degree north of the Sun's centre, too close to be viewed safely.

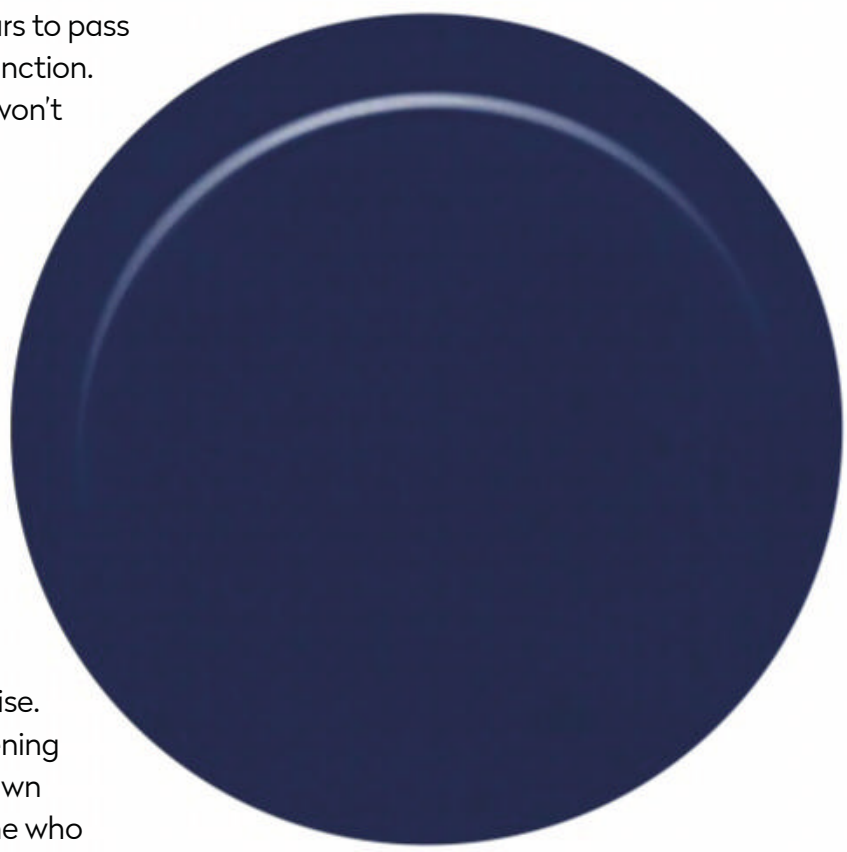
After inferior conjunction Venus reappears in the morning sky with remarkable rapidity. By 9 June it should be possible to spot the planet low above the northeast horizon just before sunrise. Like its last appearance in the evening sky, this re-emergence into the dawn twilight will reap rewards to anyone who attempts to spot the planet through a telescope as Venus appears as a large, slender crescent through the eyepiece. However, unlike its evening appearance, the phase will be growing over time.

On 9 June the planet shows a 1% phase, a delicate and truly awesome sight if you can locate it. By 16 June the phase will have grown to 5%. All the while the planet's apparent size will be large, 56 arcseconds on 9 June and 53 arcseconds on 16 June.

On 19 June, when Venus appears 7% illuminated and 51 arcseconds across, it's crescent will be occulted by a 3%-lit waning crescent Moon during daylight hours. In order to see this properly, we recommend locating the Moon or Venus during the darker portion of the dawn twilight. Once found, using an equatorially mounted scope it should be possible to keep track of the pair past sunrise and through to the occultation.

The occultation starts from 08:37 BST (07:37 UT) as seen from the centre of the UK. However, as time will vary slightly with location, we recommend looking from 08:20 BST (07:20 UT). As this occultation involves the waning lunar crescent, it's the illuminated Moon edge which encounters the planet first. Venus reappears from behind the Moon's dark edge approximately 65 minutes later, a period which again varies according to location.

▸ Turn to page 68 for more information on how to photograph this event



▲ Venus at inferior conjunction in August 2015. The planet passed the Sun by 7.8° on this date with a phase of 0.9% and apparent diameter of 57.9 arcseconds

ALL PICTURES: PETE LAWRENCE

Riding high: the noctilucent cloud (NLC) season returns

Noctilucent cloud season 2020 kicks off

BEST TIME TO SEE: All month long at the stated times

It's noctilucent cloud (NLC) season once again, June and July representing the best possible times to catch sight of these elusive, high altitude ice clouds. NLCs have a direct connection with astronomy. They are a high-altitude phenomenon, occurring at a height of 82km in the mesosphere. NLCs are ice sheets composed of myriad tiny ice crystals. The seeding particles around which these ice crystals form is predominantly meteor dust.

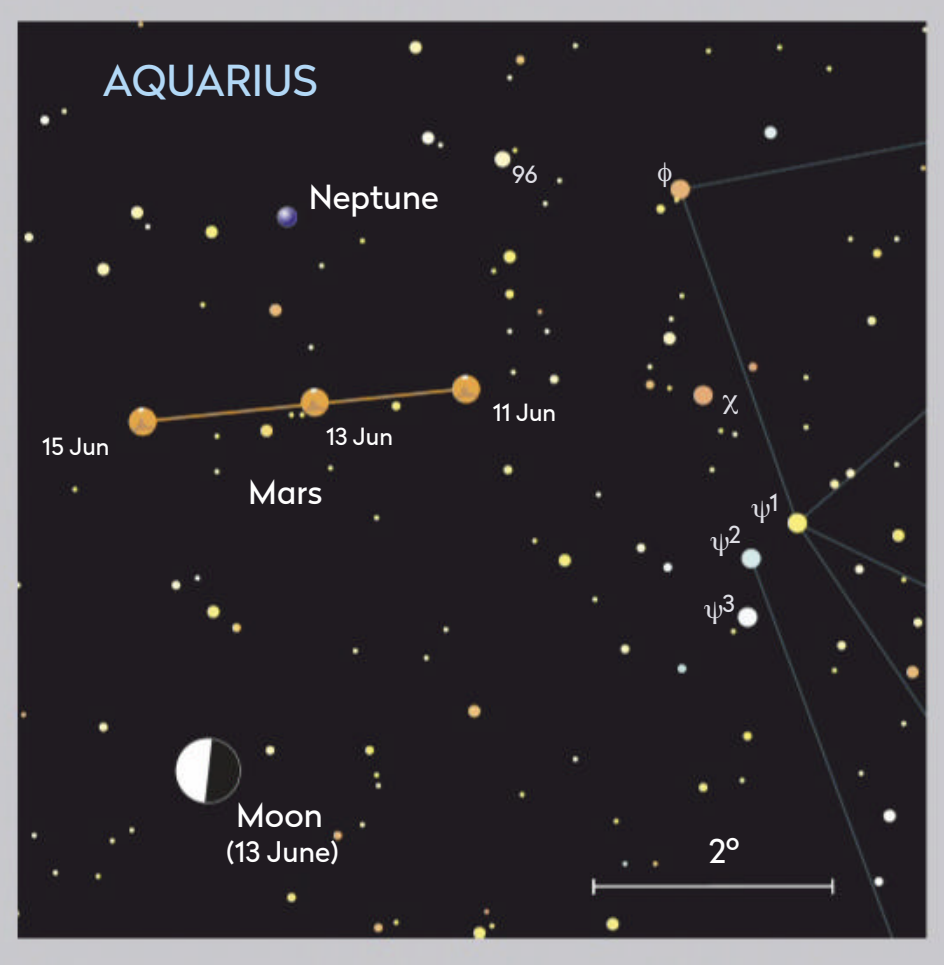
As a meteoroid vaporises in the atmosphere, it leaves tiny dust particles behind. When these encounter supercooled water vapour in the mesosphere, tiny ice crystals form around them, creating the ice sheets that appear as noctilucent clouds.

Being so high, these ice sheets remain bathed in sunlight for a time after the Sun has set for us on the ground. As they reflect sunlight pretty well, they appear illuminated against the deep twilight of a summer night. There is no guarantee that they will appear at all and a bright display one night doesn't mean there will be a display on the next.

The short June nights are manageable in this respect. Start looking low above the northwest horizon 90-120 minutes after sunset or a similar time low above the northeast horizon before sunrise. A display may appear in the northwest, track through north and end in the northeast.

NLCs appear to shine against a darkened sky – hence the name 'noctilucent' which means night shining. They typically have a delicate network-like appearance which remains low in the sky as seen from the UK. However, it has been noted that in recent years the tendrils of NLCs can extend high, especially as dawn approaches. Last year we had several bright, dramatic displays. Only time will tell what 2020 has in store.

► **For a beginner's guide to noctilucent clouds turn to page 26**



▲ Mars will appear closest to Neptune on 13 June in the morning sky

Mars and Neptune

BEST TIME TO SEE: Early hours of 11-15 June

Planetary conjunctions aren't that uncommon and although they have little scientific interest, when bright planets are involved such as Mercury, Venus, Mars, Jupiter or Saturn, the view can be impressive. Where the dimmer worlds of Uranus and Neptune are involved, it's the challenge of spotting them close to their brighter neighbours which creates the pull.

On 13 June brightening planet Mars sits close to the dim outer planet Neptune. Mars shines at mag. –0.2 and is easy to identify because of its distinct salmon-pink colour. Neptune is faint and will be easily lost against the bright background June morning sky.

The best strategy is to locate Mars first and use it as a stepping-stone to locate Neptune. On 13 June, Neptune is positioned 1.7° north-northwest of Mars but the distance isn't vastly different several days before or after this closest apparent approach.

Catching the pair early is the best way to secure Neptune and this will require you to have a flat east-southeast horizon. Binoculars or a scope using a low power eyepiece are the best choices for grabbing the pair visually. Alternatively, a camera setup with a 400mm or shorter focal length lens should help you secure them.

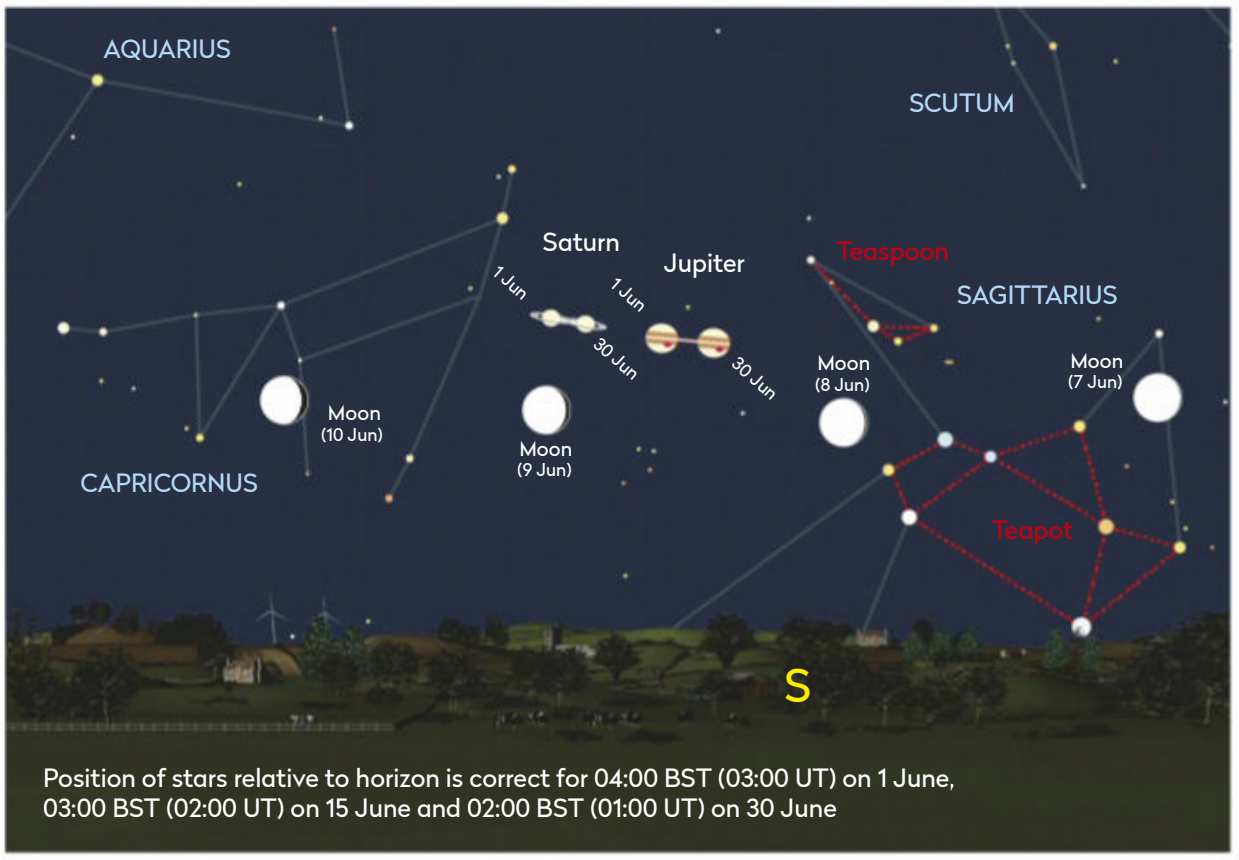
THE PLANETS

Our celestial neighbourhood in June

PICK OF THE MONTH

Jupiter

Best time to see: 30 June, 02:00 BST (01:00 UT)
Altitude: 15°
Location: Sagittarius
Direction: South
Features: Belts, Great Red Spot, atmospheric disturbances, Galilean moons
Recommended equipment: 150mm or larger



Position of stars relative to horizon is correct for 04:00 BST (03:00 UT) on 1 June, 03:00 BST (02:00 UT) on 15 June and 02:00 BST (01:00 UT) on 30 June

Jupiter is the largest planet in the Solar System, an example of an object known as a gas giant. When you look at it through a telescope, you're looking at the top of the planet's extensive atmosphere. Here you can see all sorts of atmospheric phenomena. Spinning once on its axis in just shy of 10 hours, the planet bulges at its equator, appearing oblate even through a small instrument. Most obvious visually are the two dark bands that encircle the planet to the north and south of the equator. These are known as the north equatorial belt (NEB) and south equatorial belt (SEB).

The southern edge of the SEB has a scalloped-out feature in which sits the most famous long-term storm in the entire Solar System, Jupiter's Great Red Spot. The scalloped-out feature is known as the Red Spot Hollow. All of these features are just about visible in a 100mm scope at around the 100x magnification mark, increased aperture increases visibility greatly.

Small scopes are also good at revealing Jupiter's four largest moons, the so-called Galilean moons, Io, Europa, Ganymede and Callisto. Use our moon position guide (opposite) to help identify them.

Jupiter is currently rather low as seen from the UK and this renders fine detail difficult to see due to atmospheric instability.

Saturn and Jupiter are currently quite close ahead of a 'Great Conjunction' which is due to take place at the end of 2020.

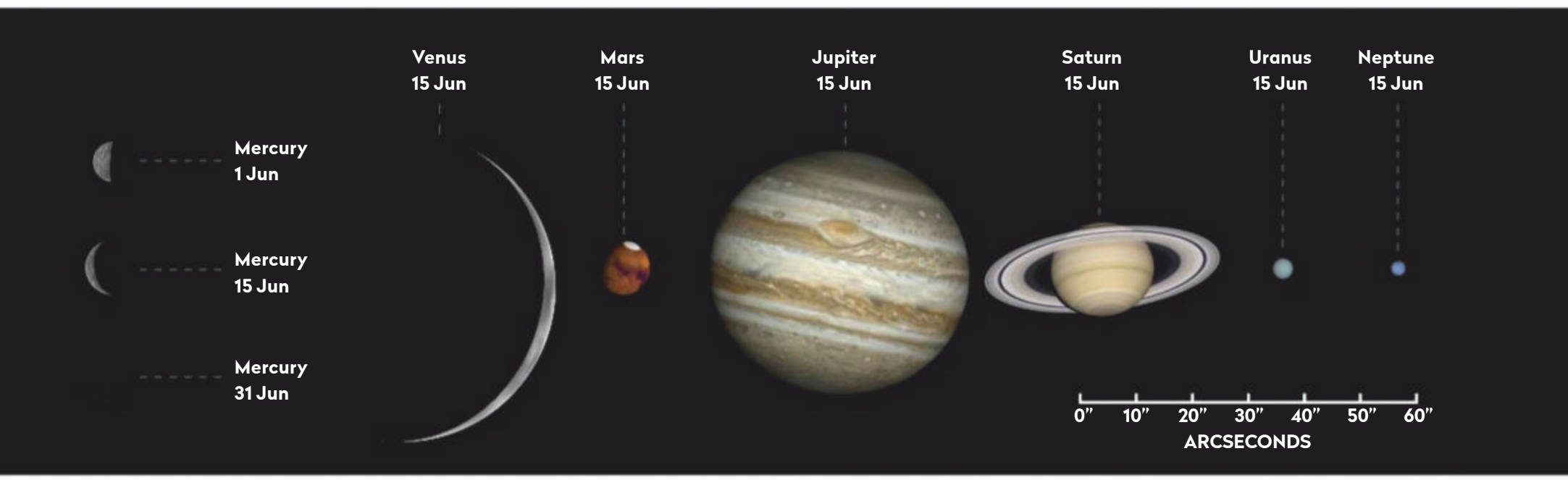
Throughout the month, Jupiter shines brightly. On 1 June it will be mag. –2.4, increasing to –2.6 by the month's end as it approaches opposition in July. An 87%-lit waning gibbous Moon lies near to Jupiter and Saturn on 9 June.

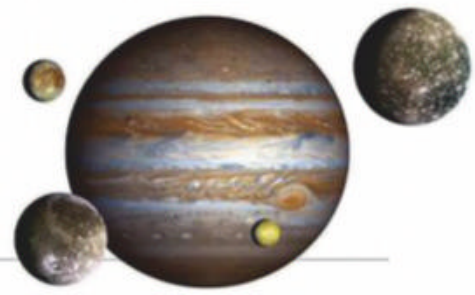
▲ **Jupiter will shine brightly throughout the month of June**

PETE LAWRENCE X 3

The planets in June

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 1 June, 40 minutes after sunset
Altitude: 9.5° (low)
Location: Gemini
Direction: West-northwest
Mercury is an evening object, technically for the whole of June. Unfortunately, unlike last month's spectacular evening appearance, its brightness drops fast along with its post sunset altitude, meaning it's likely to be lost from view from mid-month onwards. Greatest eastern elongation occurs on 4 June when it will appear separated from the Sun by 23.6°.

Venus

Best time to see: 30 June, 1 hour before sunrise
Altitude: 5°
Location: Taurus
Direction: East-northeast
Venus reaches inferior conjunction on 3 June, when it lines up with the Sun and cannot be seen. Sometimes we can view Venus as it passes through inferior conjunction, but some are better than others as the apparent distance from the Sun varies from one conjunction to the next. Here, the apparent separation is too small to be safe, Venus passing within half a degree of the Sun's centre on 3 June.

Venus returns to the morning sky after inferior conjunction, rising 1.5 hours before the Sun by 30 June. Although its position will not be as favourable as it was in the evening sky it will appear bright at mag. –4.3 at June's close.

A special event occurs on the morning of 19 June when Venus will be occulted by the waning crescent Moon. At the time Venus will be showing a 7% crescent and appear 51 arcseconds across. The Moon will show a 3% crescent at this time. The occultation takes place from 07:37 UT and reappearance starts at 08:43 UT. See page 42.

Mars

Best time to see: 30 June from 03:00 BST (02:00 UT)
Altitude: 17°
Location: Pisces
Direction: East-southeast
Mars is now improving despite its apparent eastward travel against the stars keeping it tucked into the dawn twilight. On 1 June a scope will show mag. +0.0 Mars to have a 9 arcsecond disc with a phase of 84%. At the month's close it will have increased to mag. –0.5.

Saturn

Best time to see: 30 June, from 02:00 BST (01:00 UT)
Altitude: 16.5°
Location: Capricornus
Direction: South
Saturn appears just east of Jupiter, low above the southern horizon in the early hours. The off-white planet appears to brighten from mag. +0.7 to +0.5 during June. An 87%-lit waning gibbous Moon is nearby on the morning of the 9 June.

Uranus

A morning planet which is now too entrenched in the dawn twilight for serious viewing.

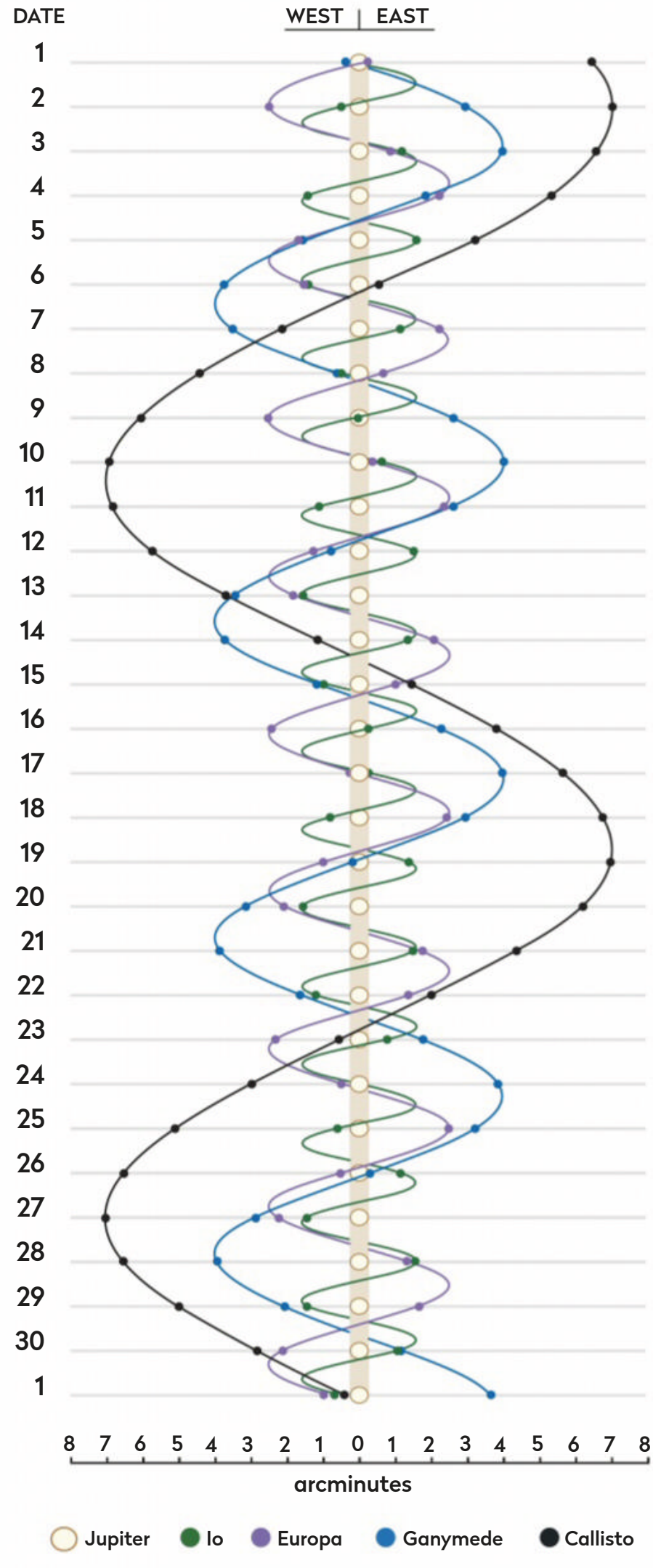
Neptune

Best time to see: 13 June, from 02:00 BST (01:00 UT)
Altitude: 5° (very low)
Location: Aquarius
Direction: East-southeast
Low in the east-southeast as dawn twilight begins to brighten. Mars is nearby on 13 June and mornings near this date. At mag. +7.9 Neptune is lost in dawn's twilight. A last quarter Moon sits below Mars and Neptune on the 13th.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: JUNE

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – JUNE

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 June at 01:00 BST
15 June at 00:00 BST
30 June at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in June*

Date	Sunrise	Sunset
1 Jun 2020	04:48 BST	21:29 BST
11 Jun 2020	04:42 BST	21:38 BST
21 Jun 2020	04:41 BST	21:43 BST
1 Jul 2020	04:46 BST	21:42 BST

Moonrise in June*

Moonrise times

1 Jun 2020, 15:36 BST	17 Jun 2020, 02:59 BST
5 Jun 2020, 21:22 BST	21 Jun 2020, 04:44 BST
9 Jun 2020, 00:27 BST	25 Jun 2020, 09:10 BST
13 Jun 2020, 02:03 BST	29 Jun 2020, 14:45 BST

*Times correct for the centre of the UK

Lunar phases in June

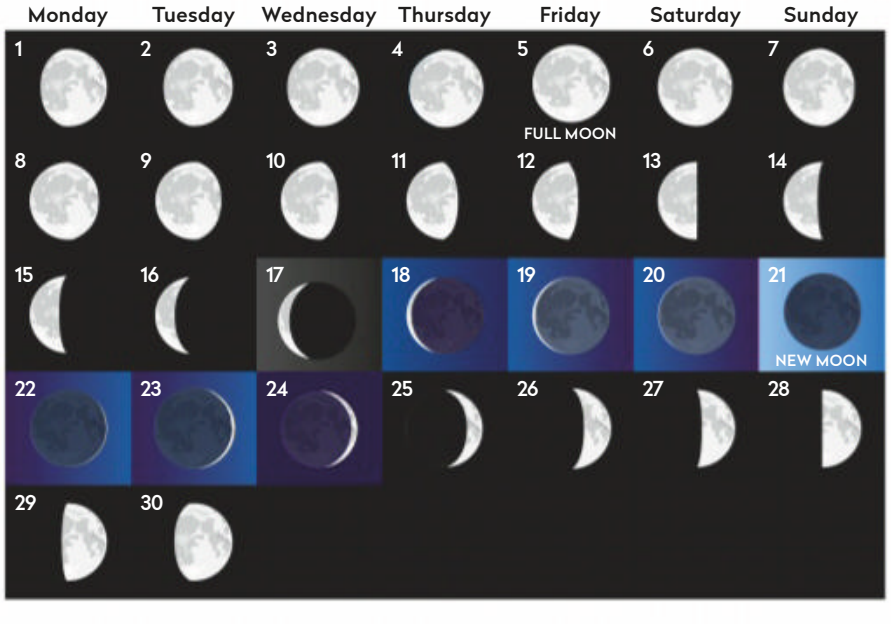
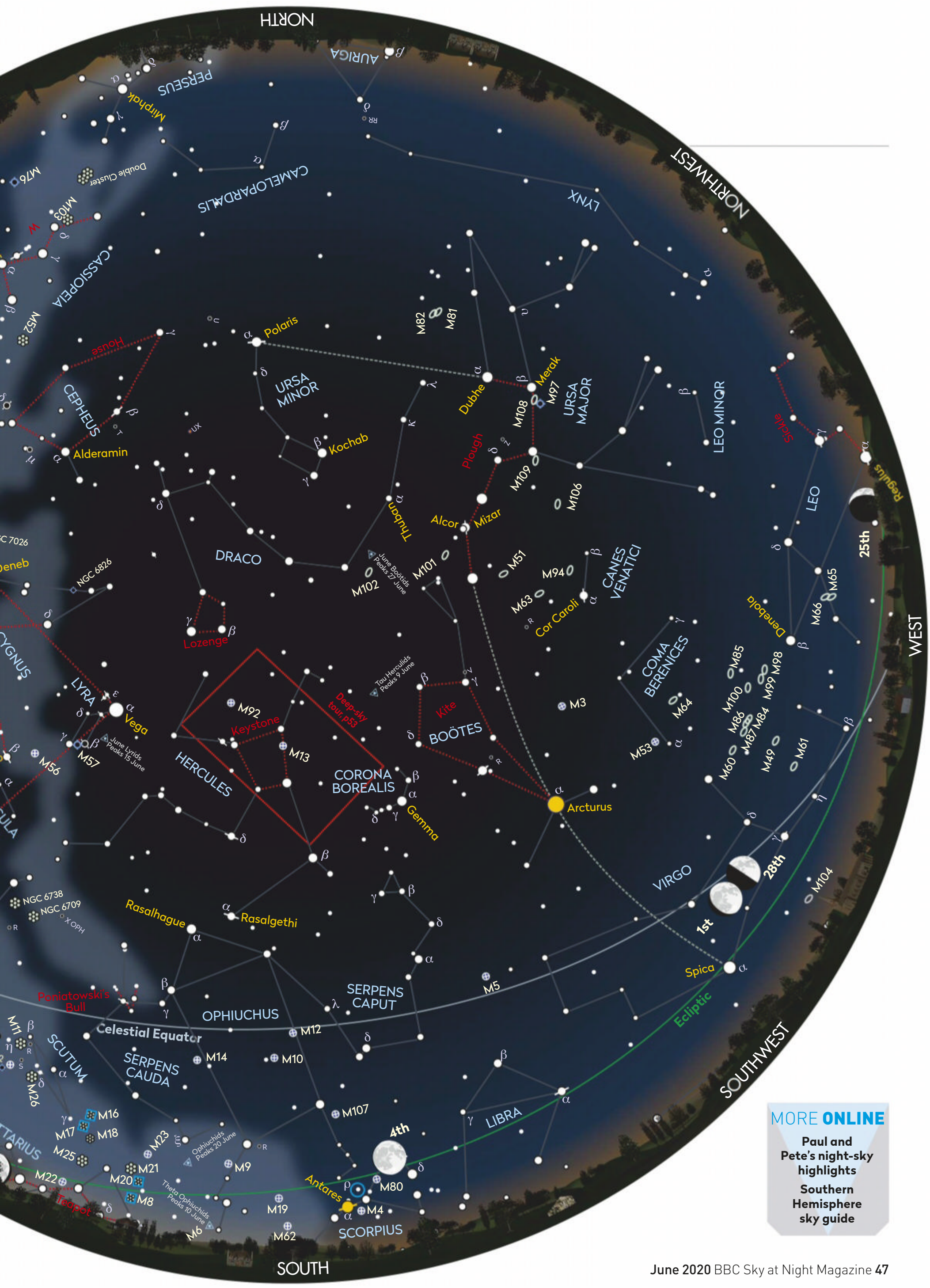


CHART: PETE LAWRENCE



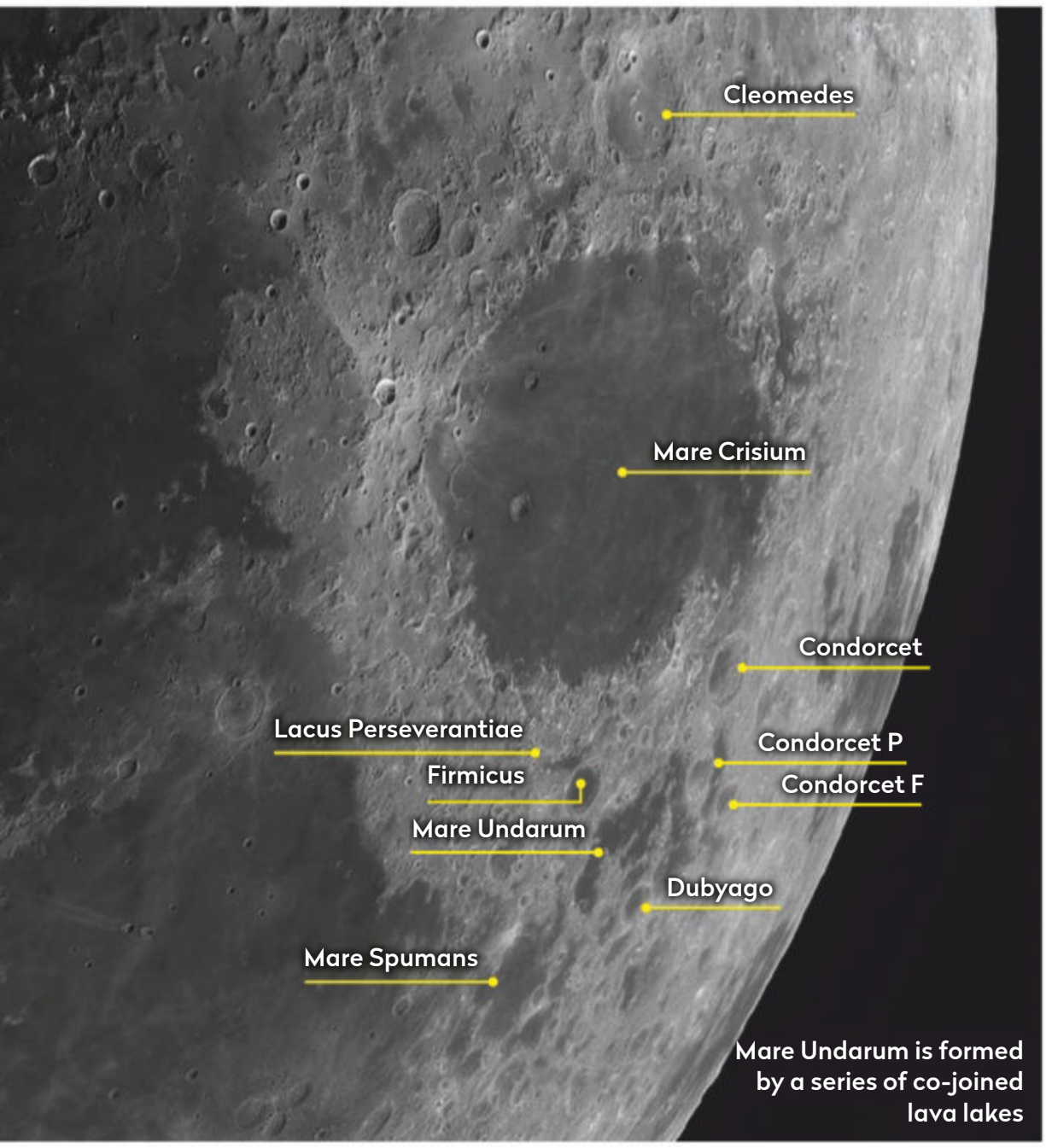
MORE **ONLINE**

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

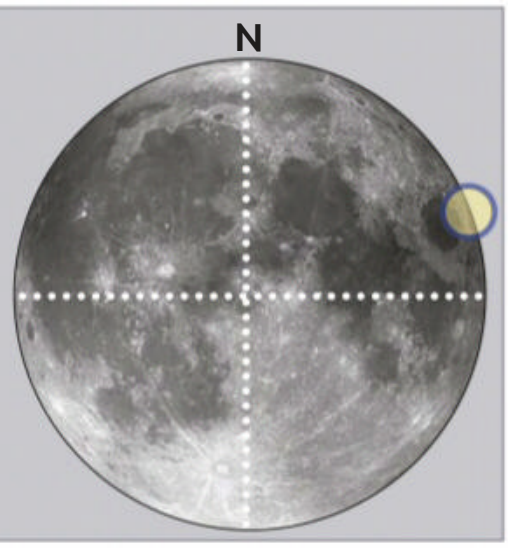
MOONWATCH

June's top lunar feature to observe



Mare Undarum

Type: Lunar sea
Size: 200 x 100 km
Longitude/latitude: 68.7° E, 7.5° N
Age: Older than 3.9 billion years
Best time to see: Two days after new Moon (22 & 23 June) and one day after full Moon (6 & 7 June)
Minimum equipment: 10x binoculars



PETE LAWRENCE X 3

Mare Crisium is one of the most recognisable features on the Moon's Earth-facing side, a dark oval patch of lava located in the northeast quadrant, measuring 620 x 570km. Less well known is the irregular patch of dark lava lying southeast of Mare Crisium, known as **Mare Undarum**, the Sea of Waves. It appears to be formed by a series of circular co-joined lava lakes. If you're not seeing much roundness here, you need to factor in foreshortening, the effect that makes a circular region look like an ellipse when it is seen at an oblique angle close to the Moon's edge.

Less well known than Mare Crisium is the patch of dark lava lying to its southeast

Mare Undarum looks like a collection of craters infilled by lava which have joined to form the contiguous area we see today. There are several craters in and around the mare which show similar characteristics; rims with dark lava-filled floors. Further south is 51km **Dubyago**, a well-formed crater with a slightly irregular shape and partially terraced walls leading to a flat, dark floor. In the north are two satellite craters associated with 74km **Condorcet** just southeast of Mare Crisium: 46km **Condorcet P** and 37km **Condorcet F** are like twins. Both have the same general structure as Dubyago and both sport smaller craters at their extreme southern rims; a 10km crater at the south of Condorcet P and a 5km crater at the south of Condorcet F. The elevated partial terraced rims leading down to a flat, dark lava filled floor is echoed by the appearance of Condorcet itself.

West of Mare Undarum is 56km **Firmicus** which also has a similar flat, dark floor. Heading west from the northwest edge of Firmicus's rim is **Lacus Perseverantiae**, the Lake of Perserverance, a 70 x 15km strip of flat, dark lava. This type of feature is fairly common here. Southwest of Mare Undarum lies **Mare Spumans**, the Foaming Sea.

Mare Undarum's irregular form can, with a bit of imagination, be gauged as being roughly circular in shape, in other words, resembling a lunar basin. Such features normally form after a large impact fractures the lunar crust allowing lava to upwell into the now depressed surface. Interestingly, the region around Mare Undarum doesn't fit this bill at all because it is elevated rather than depressed, and measurements have shown no thinning of the Moon's crust caused by an impact.

To understand what caused Mare Undarum to form, it's necessary to zoom out and take in the wider picture. The **Crisium Basin** isn't only represented by Mare Crisium. Outer basin rings run concentrically around the recognisable oval sea. The outer rings are hard to see in the south but one is easier to pick out in the north running to the north of 126km **Cleomedes**. Being over 900km in diameter, this basin ring would encompass the lava patches seen in Undarum and Spumans to the south. These seas and the infilled craters surrounding them were formed as a result of the larger Crisum basin formation, the lava flowing between the concentric basin rings essentially collecting in the lowest spots it could gravitate into.

COMETS AND ASTEROIDS

Minor planet 7 Iris reaches opposition in Sagittarius at the month's end

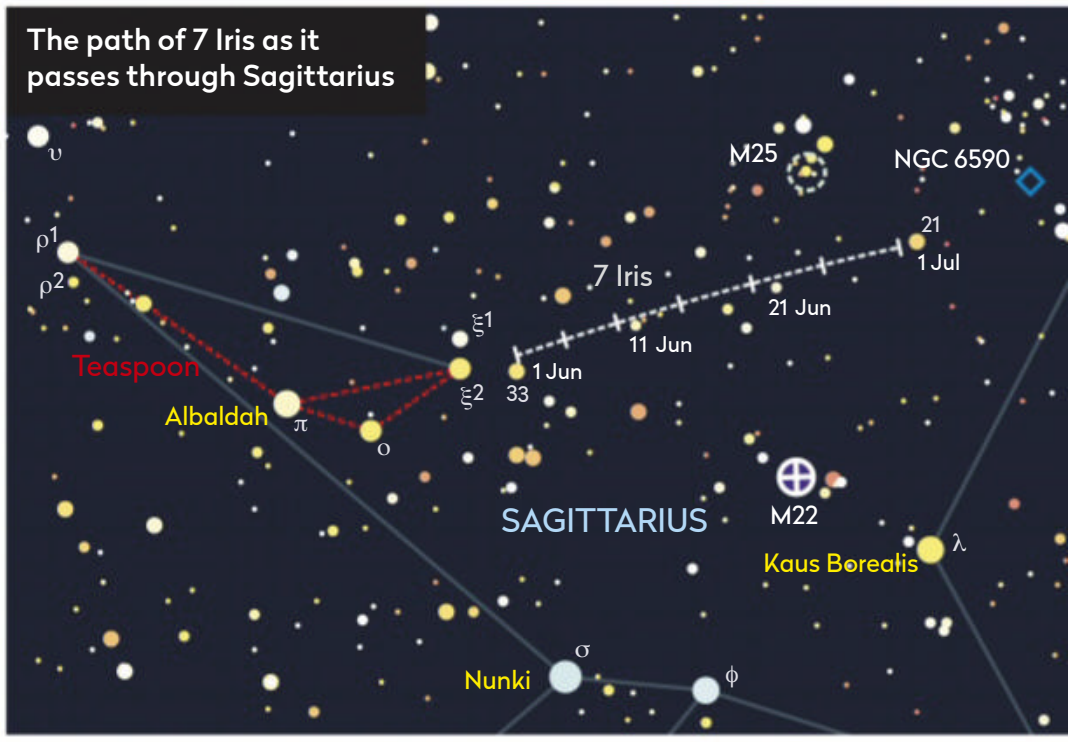
Minor planet 7 Iris reaches opposition on 28 June when it will appear at a binocular-friendly mag. +8.8 in Sagittarius. It starts its June track to the west of the lip of the Teaspoon asterism, about 40 arcminutes west of mag. +3.5 Xi^2 Sagittarii and just to the north of mag. +5.7 33 Sagittarii. On 1 June, Iris will be shining at mag. +9.6. As it approaches opposition on 28 June it will pass about 1.5° south of the rich, mag. +4.9 open cluster M25.

Iris has a mean diameter around 241km, its tri-axial ellipsoidal measurements being 268 x 234 x 180km. A tri-axial ellipsoid is a three-dimensional, oblate ellipsoidal shape which offers a convenient way to approximate the dimensions and size of an irregular shaped body such as an asteroid. It's an S-type, stoney asteroid: S-types make up around 17% of all known asteroids.

7 Iris orbits in the main asteroid belt between Mars and Jupiter. It takes 3.7 years to complete an orbit of the Sun, moving out to 2.94 AU at its farthest point, aphelion, and in to 1.83 AU at its closest, perihelion. At favourable oppositions it can reach mag. +6.7 making it the asteroid belt's fourth brightest object. At its dimmest it approaches mag. +11.4. It's mean opposition magnitude is +7.8 meaning this month's appearance is a magnitude below par.

Its dim starlike appearance will make identifying 7 Iris challenging because it'll be passing through a region of sky rich in faint background Milky Way stars. The best way to identify it will be to sketch or image the region where you think it should be located and repeat this process over a few days, weather-permitting. If you have the correct area, you should see Iris moving slowly between results.

Iris was discovered by the English astromoner John Russell Hind on 13 August 1847. It was his first asteroid discovery.



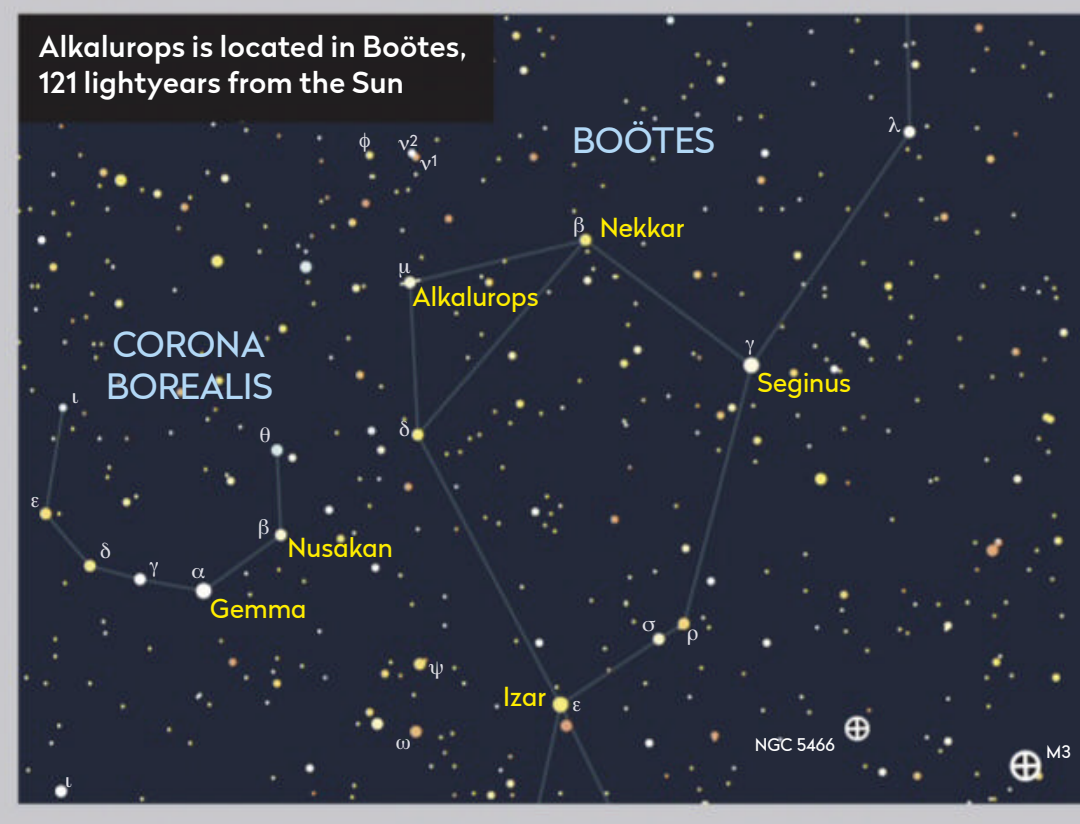
STAR OF THE MONTH

Alkalurops, a colourful pair of double stars

Alkalurops (Mu (μ) Bootis) is located close to the eastern border of Boötes, just to the northeast of the Kite asterism which represents the main body of Boötes the Herdsman. The name Alkalurops means 'a herdsman's staff' or 'club'.

As with many of the stars which appear as single objects, under close scrutiny Alkalurops isn't alone but rather a pair of double stars which may or may not be physically connected. The two pairs are designated Mu-1 (μ^1) and Mu-2 (μ^2) Bootis. The Mu-1 pair to the west carry the official name Alkalurops and appear close as seen from Earth with a narrow separation of 0.08 arcseconds, too close to be separated by amateur equipment. To us the primary appears as a F0 V star of mag. +4.3. This spectral type indicates a yellow-white colour and a main sequence dwarf-type star. Having a close physical separation, the orbital period of Mu-1 is rapid, estimated to be in the order of 300 days. The pair are referred to as Alkalurops Aa.

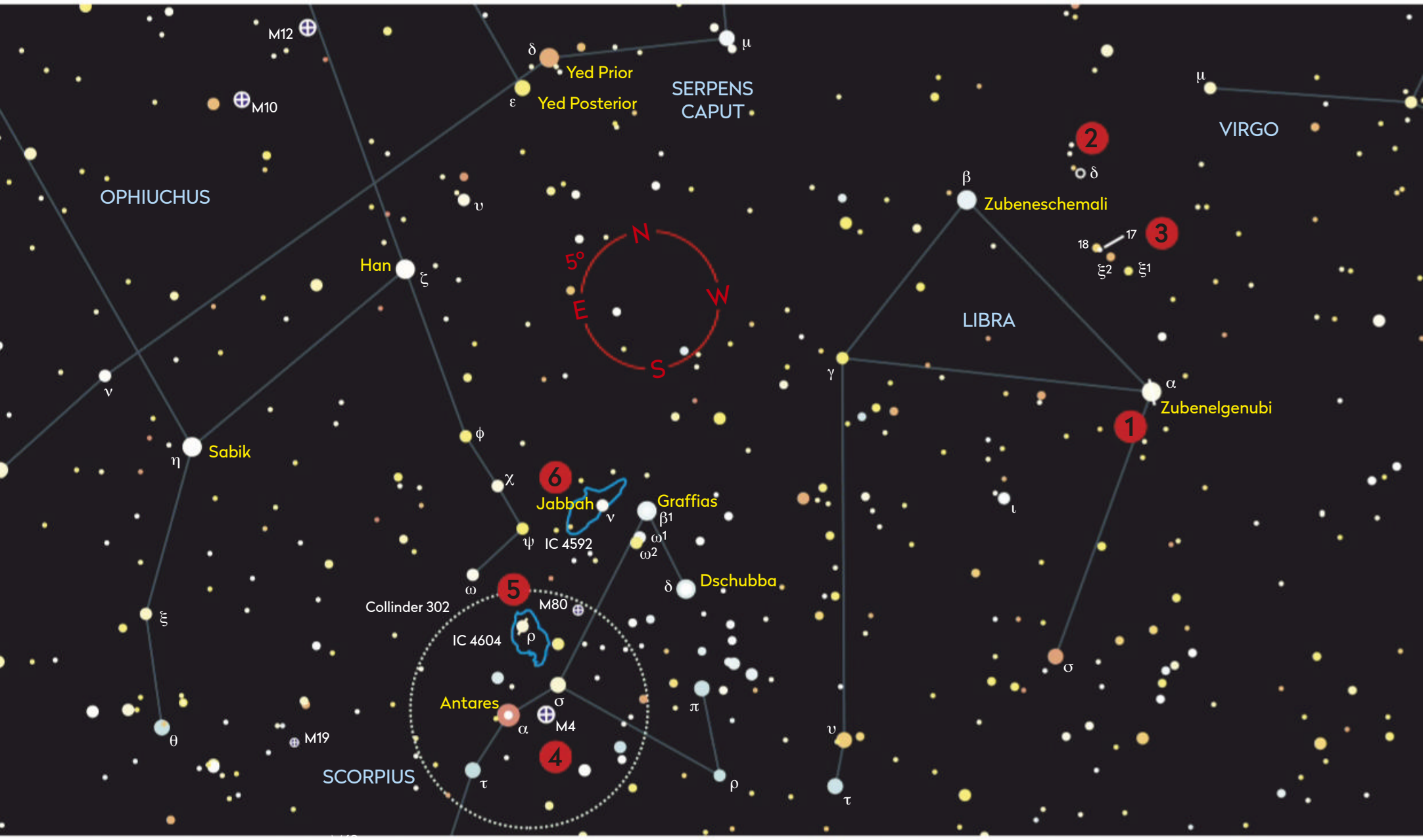
The Mu-2 pair can be split using amateur kit, having an apparent separation of 2.2 arcseconds. Designated as Alkalurops BC, their colours are distinctly more yellow than Mu-1. Their individual spectral types are of G1V (the brighter component) and G5V, the 'V' indicating that they are main-sequence dwarf stars. Their individual magnitudes are +6.5 and +7.8 and their orbital periods are significantly longer than Aa, that for BC being estimated at 260 years. The two pairs are separated by 108 arcseconds making it possible to see the Mu-1 and Mu-2 pairs in the same field of view. A magnification of x250 will confidently split the Mu-2 pair.



BINOCULAR TOUR

With Steve Tonkin

The wonderfully named star Zubenelgenubi takes the lead in our wide-field survey



1. Zubenelgenubi

10x 50 Did you know that (nearly) everyone's favourite star name is a nice easy binocular double star? Shining at mag. +2.7, Zubenelgenubi (Alpha-2 (α^2) Librae) – the name means 'the southern claw' – is visible to the naked eye. Binoculars easily reveal the mag. +5.2 companion, Alpha-1 (α^1) Librae, 3.5 arcminutes away. Although they are both around 75 lightyears distant, they may not be a true binary star.
☐ **SEEN IT**

2. Delta Librae

10x 50 The variable (mag. + 5.8 to mag. +4.4) Delta (δ) Librae lies 8° north of Zubenelgenubi and is an eclipsing binary star. This is a pair of stars, orbiting their common barycentre, in which the fall in brightness, which takes about six hours, occurs as the larger dimmer star occults the brighter one. With a period of 2.3 days, you should have several chances to notice the magnitude change. ☐ **SEEN IT**

3. Xi-1/Xi-2 and 17/18 Librae

10x 50 Approximately mid-way between Delta Librae and Zubenelgenubi lie two easy pairs of stars. The wide pair of orange stars is mag. + 5.8 Xi-1 (ξ1) and mag. +5.4 Xi-2 (ξ2) Librae and 0.5° northeast is the other pair, 17 and 18 Librae. These are optical doubles, meaning their proximity is a line of sight illusion: there is 50 lightyears between 17 and 18, and more than 200 lightyears between Xi-1 and Xi-2. ☐ **SEEN IT**

4. M4

10x 50 M4 is nearly 1.5° west of the bright orange-red Antares (Alpha (α) Scorpii). It is only 7,000 lightyears away, making it appear rather loose, and is one of few globulars in which some structure can be detected with 10x50 binoculars. M4 lies on the edge of the Milky Way and seems to be connected by several chains of stars to a beautifully rich star field that is more pleasing in binoculars than in a telescope.
☐ **SEEN IT**

5. Rho Ophiuchi

10x 50 The mag. +5.0 Rho (ρ) Ophiuchi lies 3° north of M4. It is a component of a triple star, whose 7th magnitude companions are situated 2.5 arcminutes to the north and west, making it look like Mickey Mouse. If the sky's good, averted vision can help you detect a brightening of the surrounding sky: 10x50s are ideal for detecting this nebulosity. ☐ **SEEN IT**

6. Jabbah

15x 70 Identify Graffias (Beta-1 (β^1) Scorpii) and pan 1.5° east to Jabbah (Nu (ν) Scorpii). You will find it has two mag. +7.6 companions, about 10 arcminutes to the southeast, but closer inspection will reveal a brighter (mag. +6.5) companion 40 arcseconds away on the other side. These are both multiple stars, likely to be triple and quadruple, so together they could comprise a septuple star system. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Jupiter's four Galilean moons are easy to spot, but how many others can you find?

With Jupiter now clearly visible low in the south, this month's challenge is to capture some of its fainter moons. Jupiter has a lot of moons; 79 at the last count. You'd never know looking at the planet through an amateur scope because only four of them are easy to spot. These are the four so called Galilean moons, Io, Europa, Ganymede and Callisto. The reason for the apparent disparity between the total moon count and the number seen through the eyepiece is down to size. The four Galileans are huge and appear bright, the remaining 75 are small and quite faint.

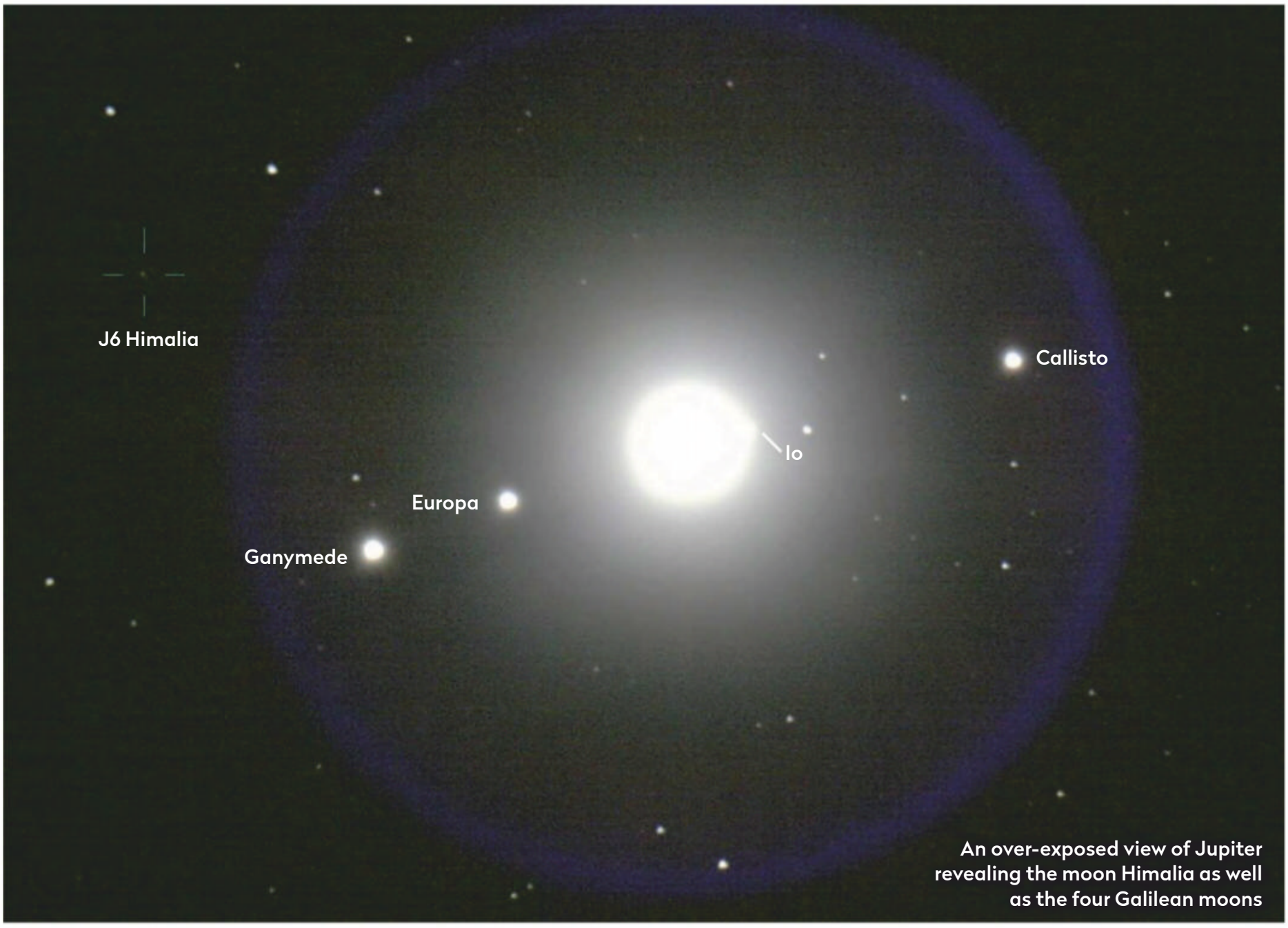
However, four is not the limit for amateurs and with a bit of vigilance, others may be seen or imaged. The moons which lie within the magnitude reach of larger amateur scopes are Amalthea at mag. +14.1, Himalia at mag. +14.8, Thebe at mag. +15.7, Metis at mag. +17.6 and potentially Lysithea at mag. +18.4.

The best time to try for them is when they are close to an elongation, in other words when they appear furthest from Jupiter. There are a number of apps and programs available which show their positions, including the free Jupiter Guide, the freeware version of Stellarium and the popular freeware planetarium program Cartes du Ciel which may be downloaded from **www.ap-i.net/skychart/en/start**. This program has an option to 'Show the faint satellites of the outer planets' (under the 'Setup: Solar System' option at the bottom of the 'Solar System' tab). With this checkbox ticked, it will show the positions of the brighter faint Jovian moons.

Some of the potential amateur targets mentioned above will be compromised due to their proximity to bright Jupiter. Thebe and Metis for example, never appear to wander too far from the planet and this will make imaging them extremely difficult. Amalthea is a good moon to start with although its maximum elongation from Jupiter isn't much beyond an apparent Jupiter diameter. Himalia is slightly dimmer but does have the virtue of appearing to move much farther from the planet.

Run a simulation using a program which shows the moons' positions and determine when Amalthea will be close to elongation at a time when Jupiter is at its highest in the sky. Unfortunately, from the UK currently, Jupiter's southern position means that its maximum altitude is quite low, something which will start to improve in subsequent years.

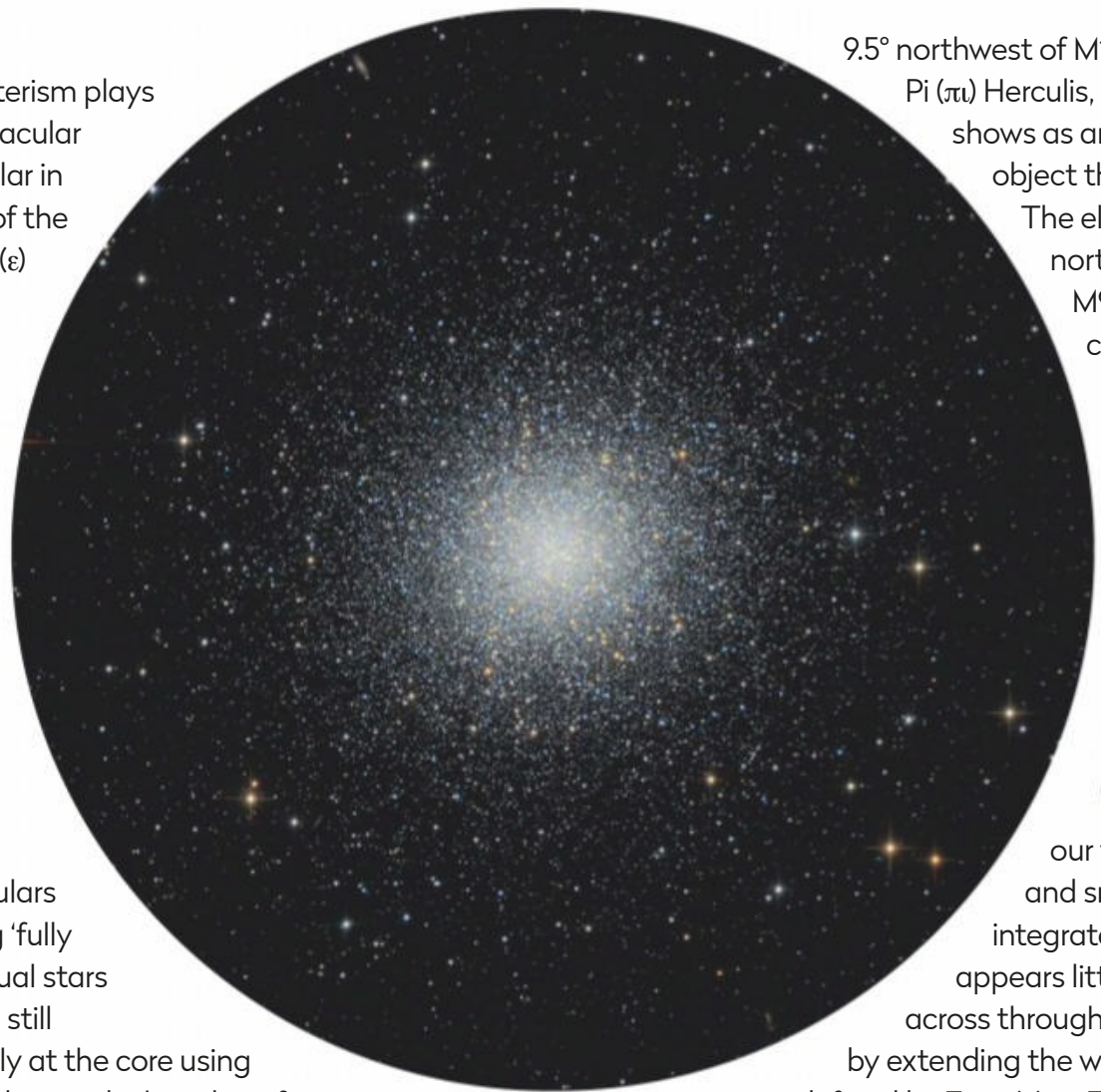
A clear, mist free night will work best. Imaging is the best course of action for capturing these moons and your imaging setup will need to be capable of capturing stars fainter than the magnitude of the moon you're after. As ever, if you manage to capture one of these dim objects, we'd be delighted to see your results.



An over-exposed view of Jupiter revealing the moon Himalia as well as the four Galilean moons

DEEP-SKY TOUR

We explore the celestial highlights around the Keystone asterism in Hercules



▲ **Begin this month's tour with the Great Globular Cluster, M13, in Hercules**

1 M13

The Keystone asterism plays host to the spectacular object M13, the Great Globular in Hercules, located one third of the way along the line from Eta (ε) to Zeta (ζ) Herculis. M13 is a treat through any instrument. A 150mm scope partially resolves the cluster's core. Look out for three dark dust lanes converging to form a pattern called 'the propeller' southeast of the core. A 200mm scope shows more stars individually across M13's centre, larger apertures only improving its resolved appearance. Although globulars are often described as being 'fully resolved', this means individual stars are seen in front of the hazy, still unresolved core. Look directly at the core using a medium to high power and towards the edge of vision you should see 'strings' of stars heading out towards the edge of the globular. ☐ **SEEN IT**

2 NGC 6207

If you've managed to locate M13, you're already in sight of our next target, a mag. +11.6 spiral galaxy known as NGC 6207. One characteristic of M13 is that it appears flanked by two foreground stars, one to the south and one to the east. Locate the mag. +6.8 eastern star and head north by 20 arcminutes to locate NGC 6207. A 150mm scope shows it as a weak elongated glow with a star-like centre. Through a 250mm instrument the galaxy has a needle like appearance, 1.75 x 0.75 arcminutes in size orientated virtually north-south. This external galaxy is 30 million lightyears distant ☐ **SEEN IT**.

3 M92

While there's no doubt that globular M92 is less visually impressive than M13, it's still a decent, bright object in its own right. M13 shines with an integrated magnitude of +5.7 and appears 15 arcminutes across in a 250mm scope. M92, which sits 9.5° northwest of M13, located 6.3° due north of Pi (π) Herculis, shines at mag. +6.4 and shows as an elongated 6 x 9 arcminute object through a 250mm scope. The elongation runs north-northeast to south-southwest. M92's 2.5-arcminute circular core appears fuzzy through a 250mm instrument but a 300mm scope will resolve this to individual stars. M92 is 14.2 billion years old and is 26,700 lightyears away. ☐ **SEEN IT**

4 NGC 6229

Globular NGC 6229 continues our trend of appearing fainter and smaller. Shining with an integrated magnitude of +9.4 it appears little more than 2 arcminutes across through a 250mm scope. Locate it by extending the western side of the Keystone as defined by Zeta (ζ) to Eta (η) Herculis. Head north for the same distance to arrive at mag. +4.8 52 Herculis. Now head north for 1.6° and you will arrive at NGC 6229. A 150mm scope just shows it. Through larger apertures, the globular remains faint without resolution, although its weak glow does show some degree of mottling. It's around 100,000 lightyears distant. ☐ **SEEN IT**

5 NGC 6058

Next is planetary nebula NGC 6058. This mag. +13.0 object is located northwest of the Keystone. The best way to locate it is to extend the north edge of the Keystone west for a fraction less than 1.2 times. The planetary lies just north of where this takes you. You can see NGC 6058 in a 150mm scope but it's faint. With an apparent size of 25 x 20 arcseconds such a view is likely to deliver an object resembling a faint star. The central star shines at mag. +13.8 and is evident through a 250mm or larger scope at over x150. ☐ **SEEN IT**

6 Abell 39

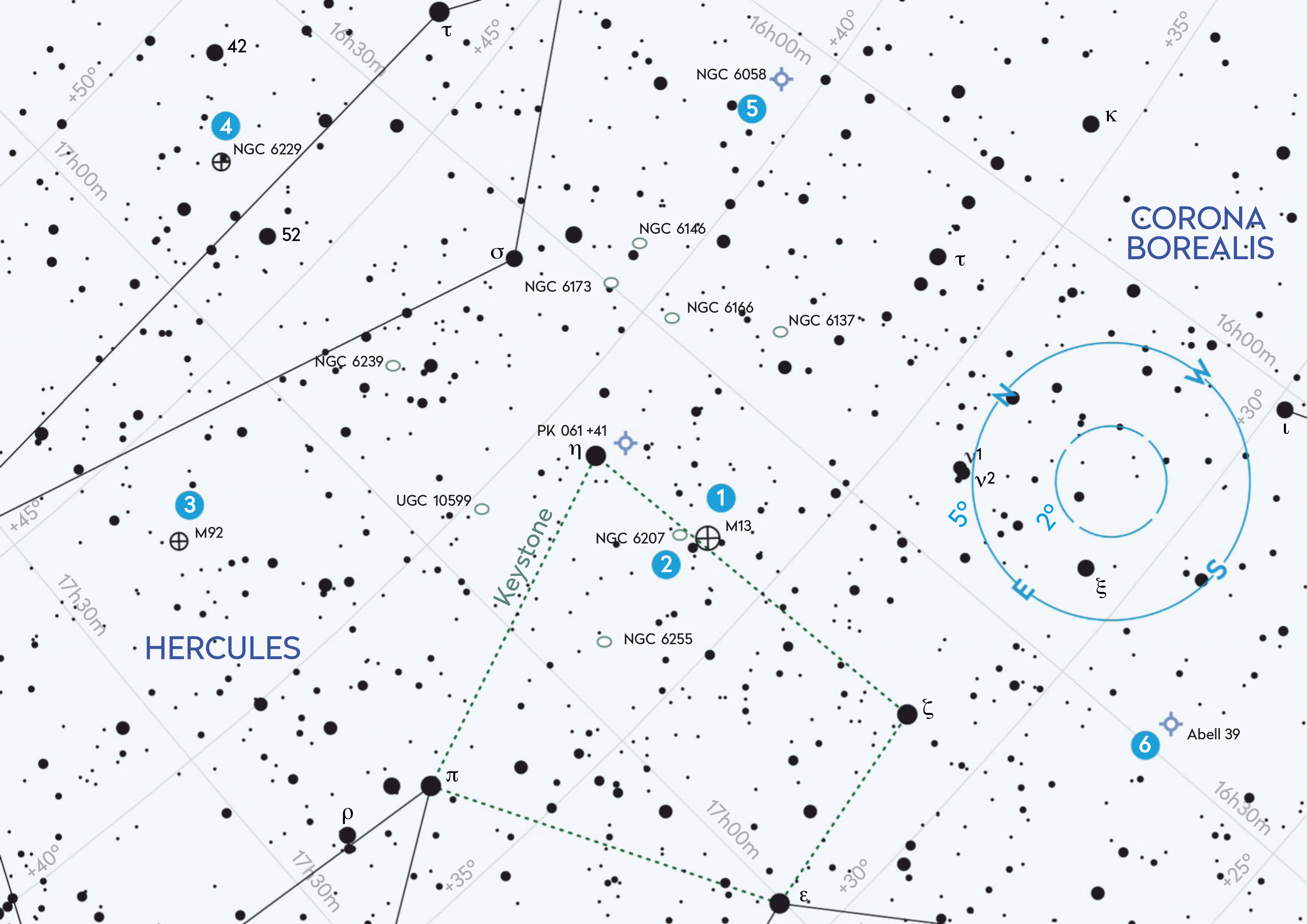
To locate the planetary nebula Abell 39, head back to the Keystone asterism and identify the star which marks the southwest corner, namely Zeta (ζ) Herculis. Abell 39 sits 4.4° southwest of this star. Abell 39 is a bit of a challenge. It has an angular diameter of 2.9 arcseconds and an integrated magnitude of +13.7. It presents a faint ghostly disc which is best seen with larger scopes. A 200mm instrument may show it but only if your skies are very dark and pristine. An OIII or UHC filter will really help but expect to use averted vision. It's located 6,800 lightyears away. ☐ **SEEN IT**

BERNHARD HUBL/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

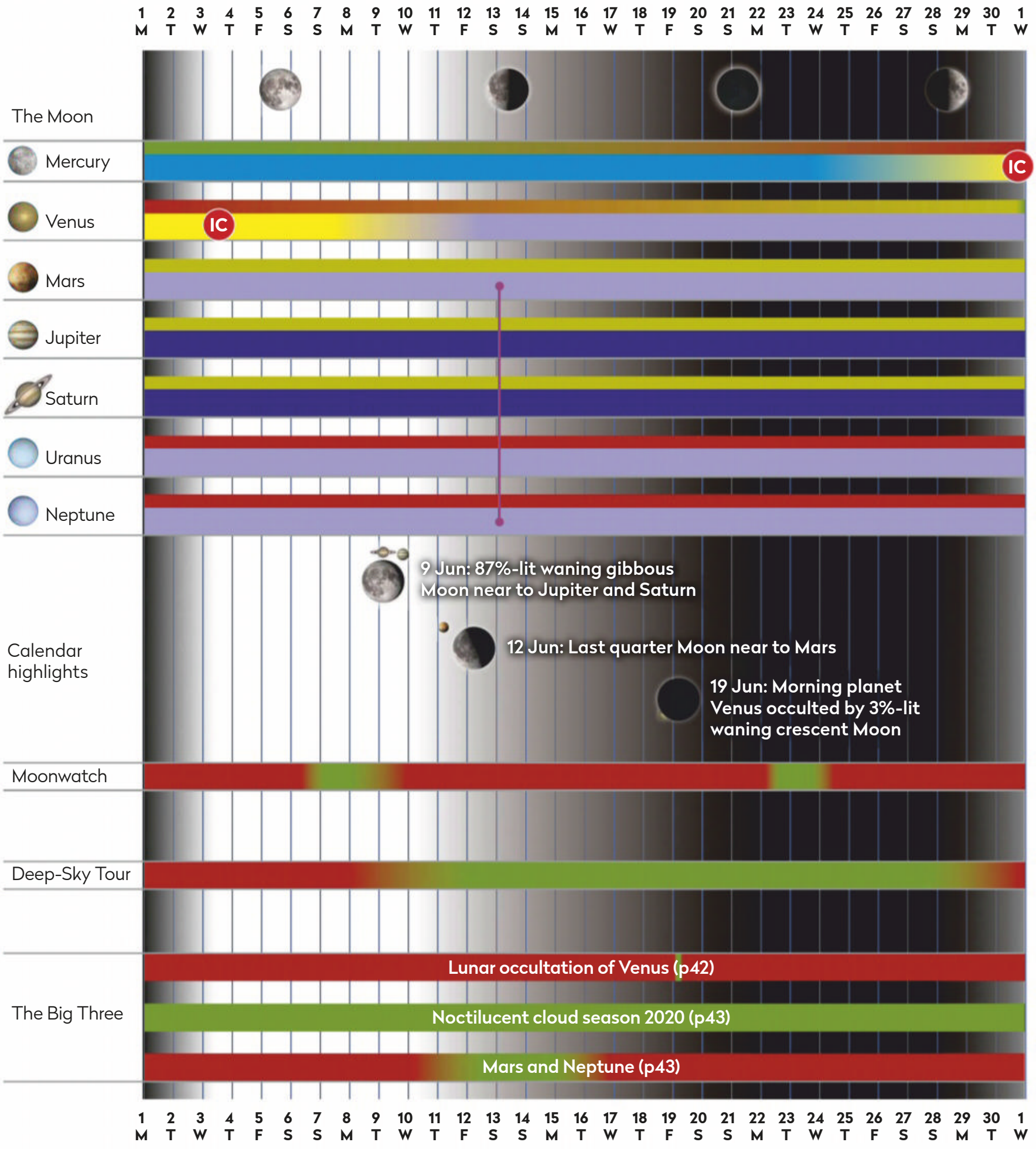
More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.


τ
42
+50°
16h30m
+45°
16h00m
+40°
+35°
NGC 6058
5
κ
4
NGC 6229
17h00m
52
NGC 6146
σ
τ
CORONA
BOREALIS
NGC 6173
NGC 6166
NGC 6137
16h00m
NGC 6239
PK 061 +41
η
ν1
ν2
5°
2°
ι
3
UGC 10599
1
M13
M92
Keystone
NGC 6207
2
17h30m
NGC 6255
HERCULES
ζ
Abell 39
6
π
ρ
16h30m
+40°
17h30m
+35°
17h00m
+30°
ε
+25°

AT A GLANCE

How the Sky Guide events will appear in June



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

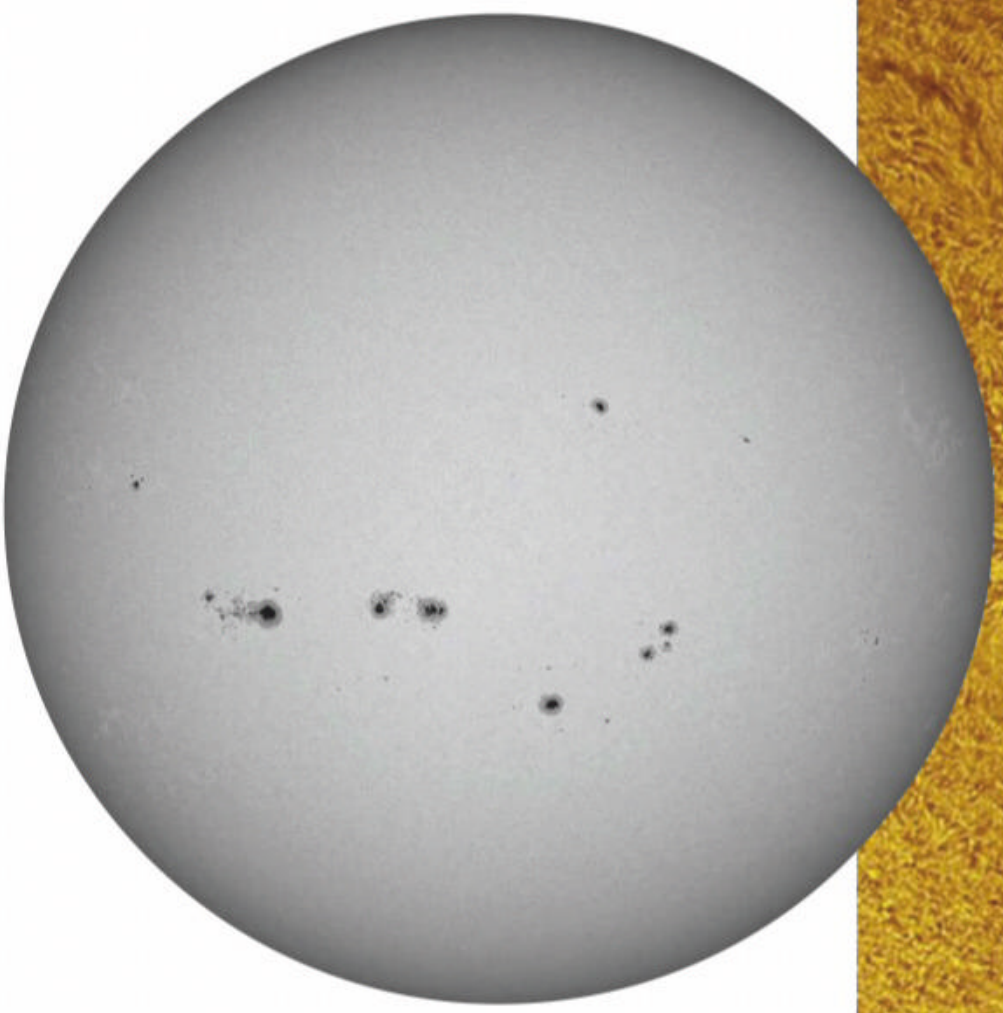
New Moon

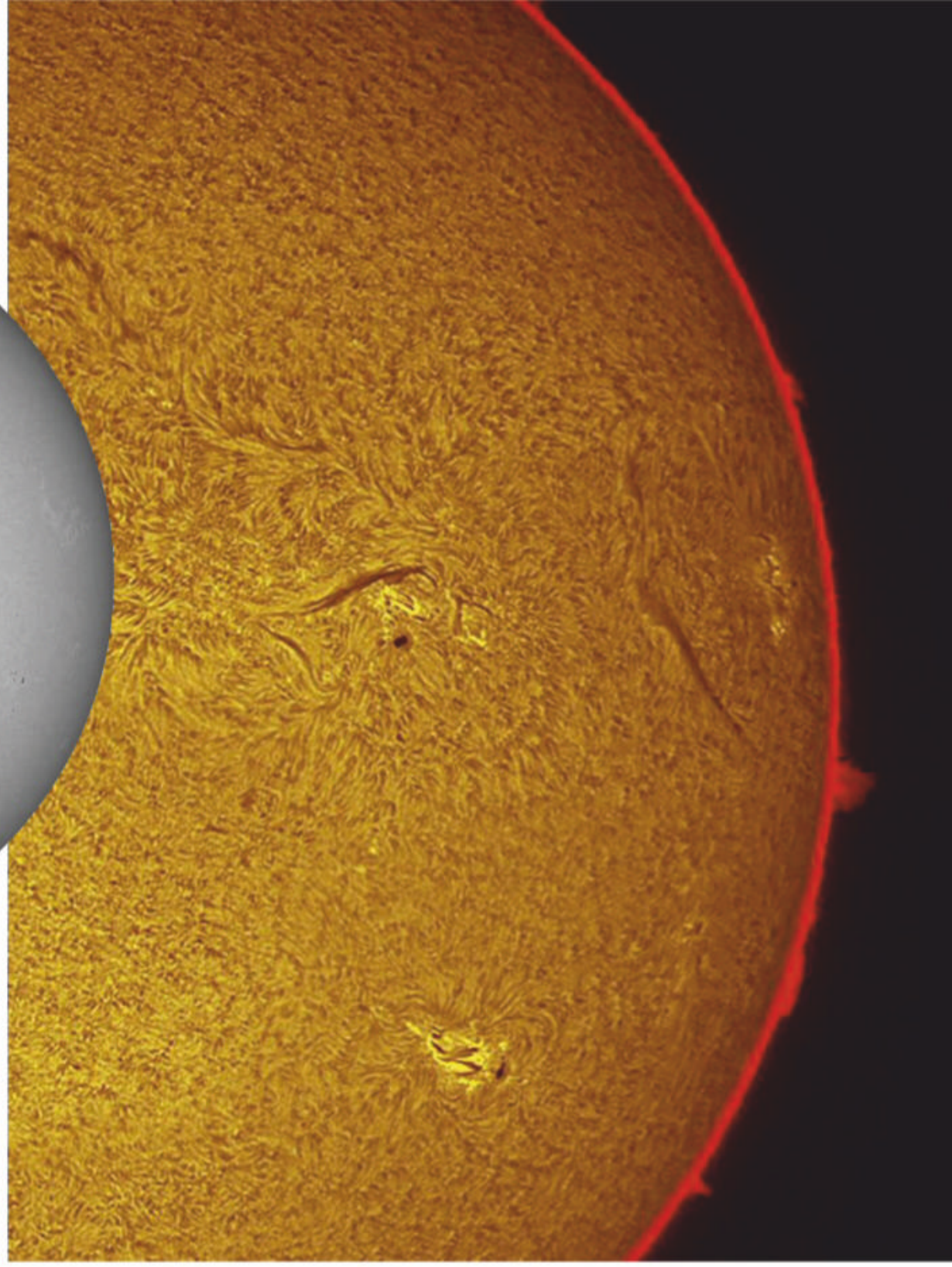
CHART BY PETE LAWRENCE

DAYTIME ASTRONOMY

Just because the nights are getting short doesn't mean you can't stargaze. **Paul Money** looks at all the ways you can observe during the daylight

SUDA YUICHI/EYEEM/ISTOCK/GETTY IMAGES





▲ **Sun spotting: (above left) in white light granulation and sunspots can be seen; while hydrogen-alpha (above) reveals prominences and filaments**

Astronomy is usually considered a night time passion featuring planets, star clusters, distant galaxies and other such wondrous sights. But in reality, there is much to be seen during daytime too. Getting your telescope out during the daylight hours can double your astro fun.

The most obvious candidate for daytime viewing is **the Sun**, but extreme care has to be taken as it can damage your eyes. Naked-eye viewing without any form of filtering is dangerous, while permanent damage can be caused by looking through optics.

A solar spectacle

One of the most spectacular solar observations is a solar eclipse, where the Moon passes in front of the Sun and blocks its light out for a short while. Eclipses can last from a few seconds to up to eight minutes, the difference in duration of solar eclipses comes down to the fact that the Moon's orbit is slightly eccentric. Sometimes the Moon is closer to Earth making totality last longer. Then when the Moon is at the other extreme – at its furthest from us – it doesn't quite cover the solar disc, and so we see a 'ring of fire', such as will be seen in Africa, the Middle East and Asia this June (see our article on page 60).

But therein lies the problem – to see an eclipse you usually have to travel, often to far flung, sometimes quite remote locations. So, as our world reels from the effects of the COVID-19 pandemic, for the time being many of us will have to be content with remote observations streamed from observatories lucky enough to be on the centre line of the eclipse shadow.

That isn't to say the Sun isn't worth looking at (with proper safety precautions) when it's not being eclipsed. White light observing allows you to safely view sunspots and surface granulation, along with

► **Daylight detail: a surprising amount can be seen on the Moon by looking through a telescope in daytime**

bright patches known as faculae near the limb of the Sun where the disc is slightly darker. Specialist hydrogen-alpha (Ha) telescopes and eyepieces bring out a view of the red chromosphere, with spectacular prominences and loops on the disc's edge that in the past were only visible during an eclipse. It's also possible to see prominences on the Sun's main disc, where they are called filaments and stand out as dark curvy lines on the surface of the Sun.

MICHAEL BREITE/STEFAN HEUTZ/WOLFGANG RIES/CCDGUIDE.COM, WILL GATER, PETE LAWRENCE X 3, M-GUCCI/ISTOCK/GETTY IMAGES

The Sun is the obvious daytime target, but it is surprising to many that **the Moon** is also viewable during the day depending on its phase. As it moves away from being close to the Sun it is initially difficult to see but during the few days either side of first quarter it becomes easily noticeable in the afternoons well before sunset. Although somewhat washed out by the blue sky it is nonetheless fascinating to use the naked eye to spot the dark 'seas' amidst the bright highland terrain. If you are an early bird and enjoy the mornings then the days either side of last quarter offer a good chance to see the Moon. Telescopes will bring out some of the features usually viewed at night – but again they will be more washed out due to the brightness and blue cast of the daytime sky – although detail along the terminator will be viewable.

As it can be reasonably obvious to spot the Moon with the naked eye it can help us find some of **the brighter planets** too. In most cases it follows that it is only when a conjunction between the Moon and a planet occurs that it can guide you to spot Venus, Jupiter, Mercury, Mars (at its brightest) and Saturn, if you are careful (see our box-out on page 59).

▲ **Planets of choice: Venus (top) and Jupiter are two worthy daytime targets**

Going on a planet hunt

On other occasions we have spotted Venus and Jupiter without the help of the Moon, but when they were highest in the south with the Sun at least 60° away from them. The sky this far from the Sun is darker, giving better contrast for spotting the two brightest planets in daytime. This is also where apps and planetarium programs can be used to give a good idea of where to look, especially if they have a compass option. If so, you can hold the phone up to the sky and then look in that direction or aim your binoculars or telescope.

Telescopically, Venus is the brightest and easiest to locate. Jupiter and Saturn look paler than they do when seen at night, and Mars is best when it's at its biggest and brightest but still appears ghostly. Mercury should be as far from the Sun as it can get for you to spot it with a scope. Use filters to help pull out a little detail, especially with Venus – an ▸

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

How to view the Sun safely

There are many ways to observe our star without risking your eyes

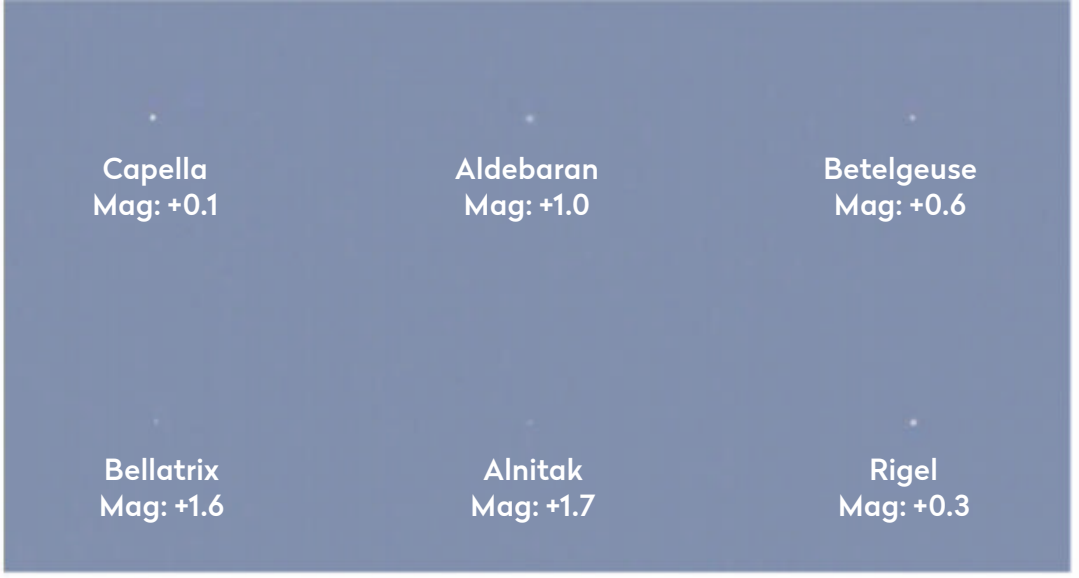
Looking directly at the solar disc is dangerous and it can potentially cause permanent damage to your eyesight. You should never look at the Sun directly, especially through an unfiltered telescope or binoculars.

Fortunately, there are many methods you can use to look at the Sun safely. One is to project the view through a telescope onto a white piece of card with a secondary card to act as a sunshade to create a dark area – that will help improve contrast. Remember to cap off any optical finder to ensure no one looks through it accidentally.

You can also buy a Hershel wedge or prism, which replaces your diagonal in a refractor and transmits a much reduced, safe amount of light to the eyepiece or camera. There are also white light solar filters that can be fixed to the front aperture or opening of all telescopes. You can buy the film and make a filter yourself or buy a pre-made one. Just make sure it fits snuggly so it won't fall off when you are looking through the scope.

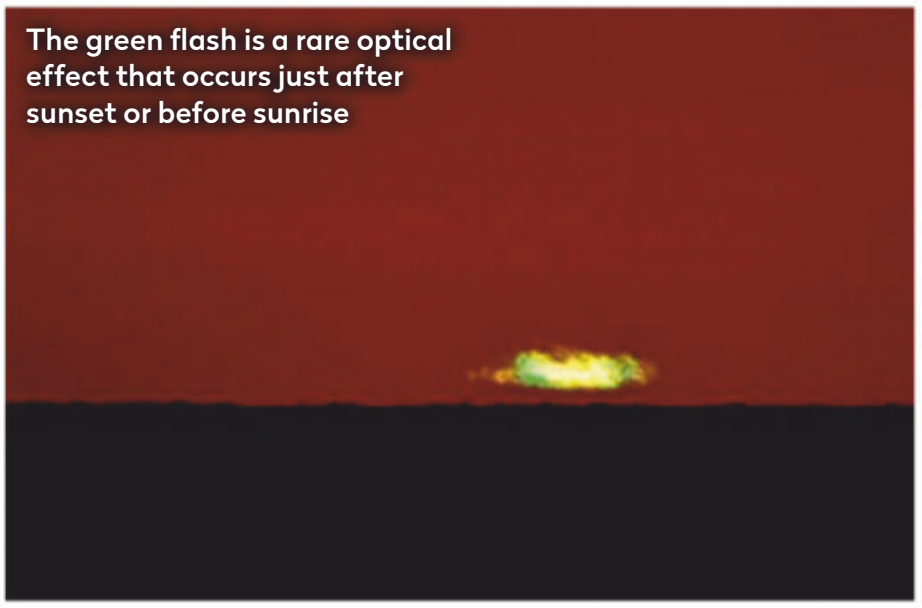
You don't have to stick to white light either. For several years now dedicated hydrogen-alpha (Ha) scopes and filters have been available to view prominences and surface detail in this wavelength. Today, this also extends to specialised eyepieces that can be used for imaging and observing in magnesium, sodium and calcium-K wavelengths too. This adds a new dimension to eclipse and transit observations by providing multiwavelength observations of our nearest star.

Safe measures: solar filters can be purchased or made to fit onto the end of your telescope



► Aim for the stars: several stars can be seen during the day, as these images taken by the author reveal

Sundogs, caused by the scattering of light from ice crystals, are usually spotted at 22° either side of the Sun



The green flash is a rare optical effect that occurs just after sunset or before sunrise

Sun pillars appear as a column of light extending 5° to 10° upwards

PAUL MONEY X 3, BLICKWINKEL/ALAMY STOCK PHOTO, SKHOWARD/ISTOCK/GETTY IMAGES, AMLPHOTO/ISTOCK/GETTY IMAGES, MICHAEL KARRER/CCDGUIDE.COM WILL GATER

► ultraviolet filter will tease out subtle markings while a red filter darkens the background sky.

The same applies to stars. Wait, what, stars? Yes, you can see them, although you will need a telescope to do so. Using the same techniques we've mentioned for planet-spotting, it's also possible to view a few of **the brightest stars** during daytime, which makes a fun and unusual project. The key is to have them in the south with the Sun over in the western sky, which for our viewing was a couple of hours before sunset. We used our 80mm ED refractor to view the primary stars of Orion, including Betelgeuse, Rigel, Bellatrix and Alnitak along with Iota Orionis, although its binary companion was not viewable. We also tracked down Capella, Procyon and Aldebaran.

For stars lower down in the sky, there's more haze to spoil the view, but we did spot Sirius with 10x50 binoculars over in the south, half an hour before sunset. With our scope we estimated that the cut-off limit was mag. +3.0, but it does depend upon sky conditions and how high they are in the sky.

Paul Money is an astronomy writer and broadcaster, and is reviews editor for *BBC Sky at Night Magazine*

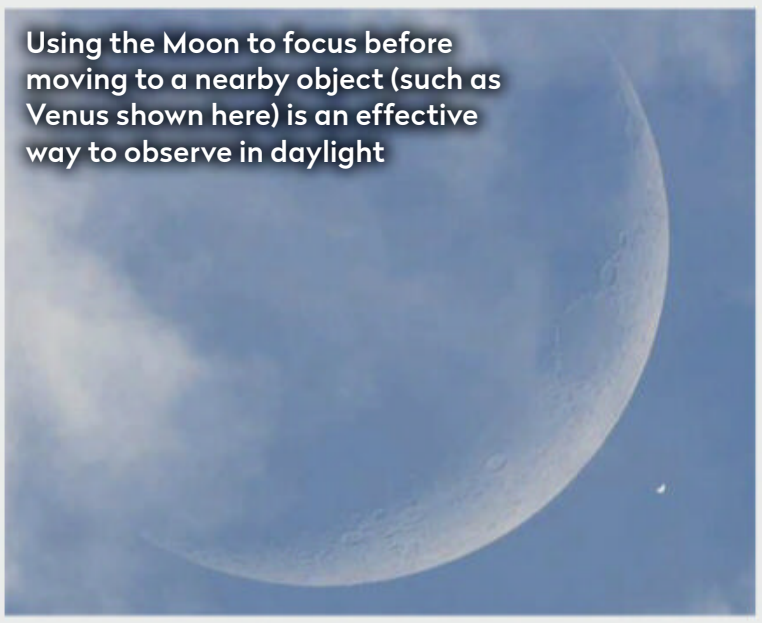
A wide array of effects

Another great thing to see is a mixture of **astronomical and atmospheric effects**. When there is a fine, high-level haze or cirrus clouds in the sky, they can cause a variety of interesting effects around the Sun. One type of these is sundogs, or parhelia. These are most often spotted at 22° either side of the Sun, and can be bright spots or patches resembling a rainbow. Associated with them are solar halos, where there is a complete hazy circle around the Sun, again at about 22° from it.

As the Sun gets low in the sky you can also look out for the Sun pillar, a column of light extending

Tracking stars and planets

Finding stars can be tricky without stellar landmarks that point the way



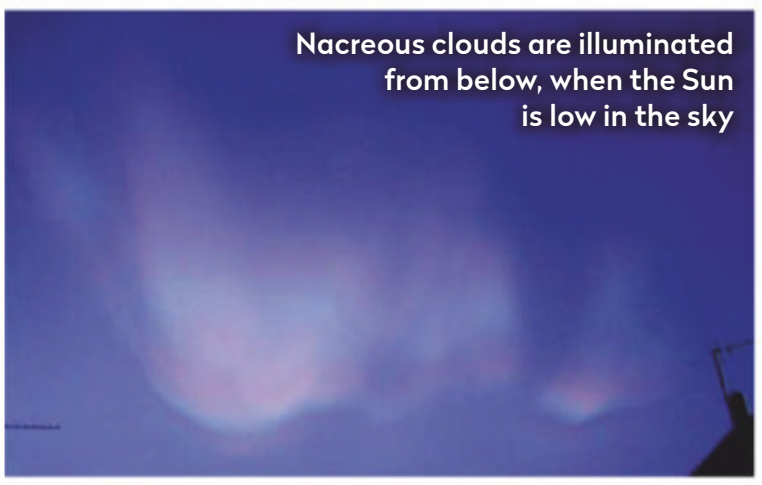
Using the Moon to focus before moving to a nearby object (such as Venus shown here) is an effective way to observe in daylight

A Go-To equipped telescope, or one equipped with setting circles on an equatorial mount, can be used to find planets and stars in daytime. In either case, if the Moon is near to your target, calibrate on it first then offset to put the target in the eyepiece. You can also use the Moon to focus first, as an even slightly out of focus planetary disc or star can be virtually impossible to see.

If the Moon is not available, you can still spot the five brightest planets and bright stars with care by using a Go-To system or with setting circles. With the latter you may have to use the Sun as a guide instead, but ensure you use safe solar filters. Then when you have moved the scope to the position of the target, remove the filter as long as the target is at least 90° away from the solar disc.

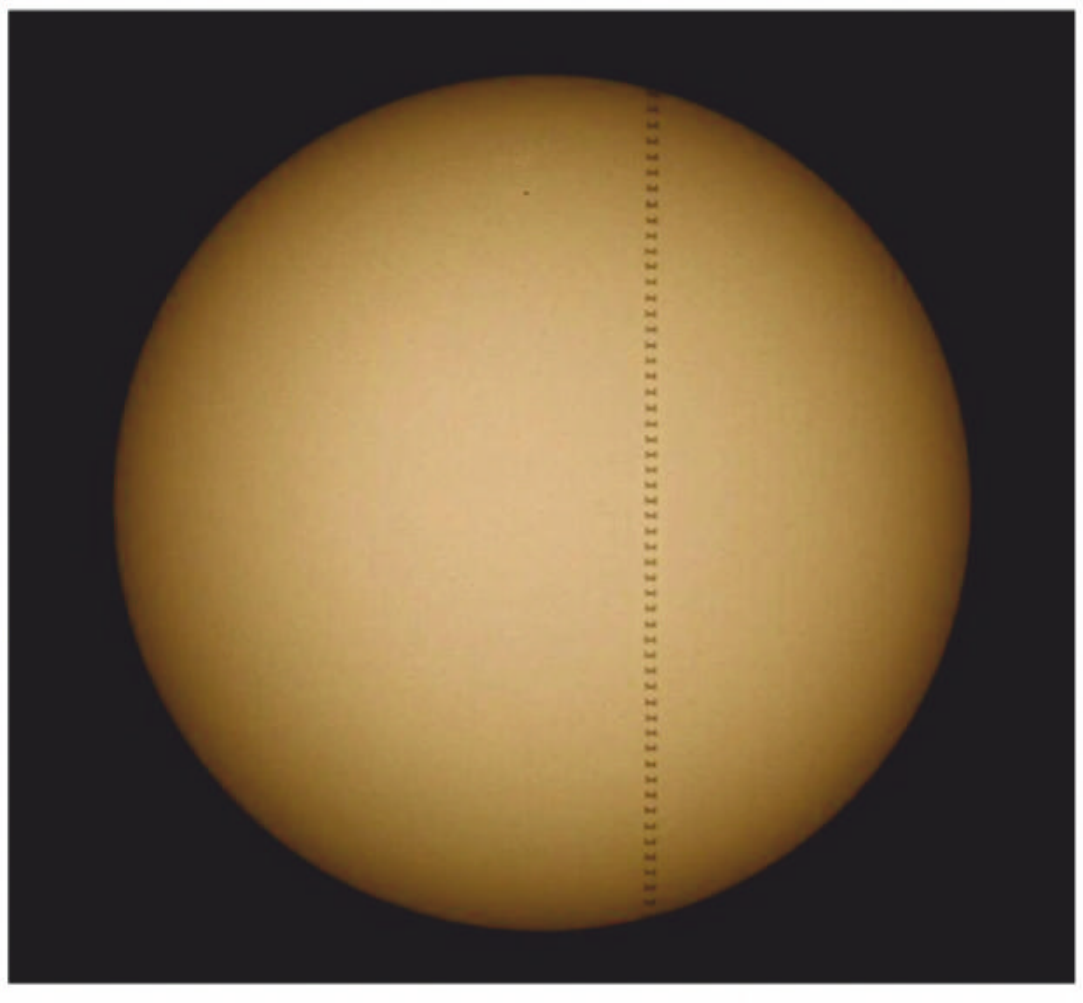
It's worth checking the elongation of the planet from the Sun by using one of the many planetarium phone apps or computer programs (for example, SkySafari Pro for a mobile or Stellarium on a PC) that gives the position for the planets and any other object during daytime.

In most cases your finderscope may pick them up too, helping you to place them in the eyepiece.



Nacreous clouds are illuminated from below, when the Sun is low in the sky

Crepuscular rays are formed by sunbeams streaming through gaps in darker clouds



▲ **Try and capture the ISS as it passes across the face of the Sun or Moon**

upwards by around 5° to 10°. If you're really lucky, you might even get to see the 'green flash' – a rare phenomenon seen just as the Sun rises and sets, where a flash of green light appears just above it on the horizon.

Sometimes the clouds themselves – the bane of every astronomer's life – can appear beautiful, such as iridescent or the rare **nacreous clouds**, sometimes called mother of pearl clouds. These can be seen a couple of hours before sunset and into twilight, and are clouds which are higher in the atmosphere, meaning that when the Sun is low they are illuminated from the bottom, creating vivid colours. Other clouds can also give rise to rays of light known as crepuscular rays, when the Sun is hidden behind a dark cloud.

It's also possible to see **the International Space Station** (ISS) during some of its daytime passes, particularly when it transits across the Moon and the Sun. It's even possible to see some **meteors** during the daytime, if you happen to be lucky enough to catch them – though you can always set up a radio meteor detector to detect them 24/7.

Whatever your passion, there is still plenty to look out for in the daytime sky so go on, check some of them out and let us know how you get on.

Full circle: an annular solar eclipse appears as a spectacular ring of fire

A ring of fire at the ROOF OF THE WORLD

This month an annular solar eclipse will be glimpsed from Africa, the Middle East and Asia, as **Jamie Carter** discovers

Have you ever seen a 'ring of fire'? It's a colloquial term for an annular solar eclipse, an event that sees the Moon temporarily block out most (but not all) of the Sun's disc.

They're normally not particularly rare – the last one occurred on Boxing Day in 2019 – but this summer's annular solar eclipse is extra special. For on Sunday 21 June, those standing under a narrow 'path of annularity' across Africa, the Middle East and Asia may glimpse phenomena not usually seen during such an event.

The solar corona is the Sun's hotter outer atmosphere, and generally speaking it's hidden from view by the brightness of the Sun's disc. It occasionally becomes visible to the naked eye during a total solar eclipse, when the Moon fits perfectly across the disc of the Sun, therefore allowing the corona to shine. It's one of the greatest sights in nature, let alone in astronomy. During totality it's also possible to see the Sun's chromosphere, its inner red atmosphere, and 'Baily's beads' – bright spots of sunlight that shine through the valleys of the Moon.

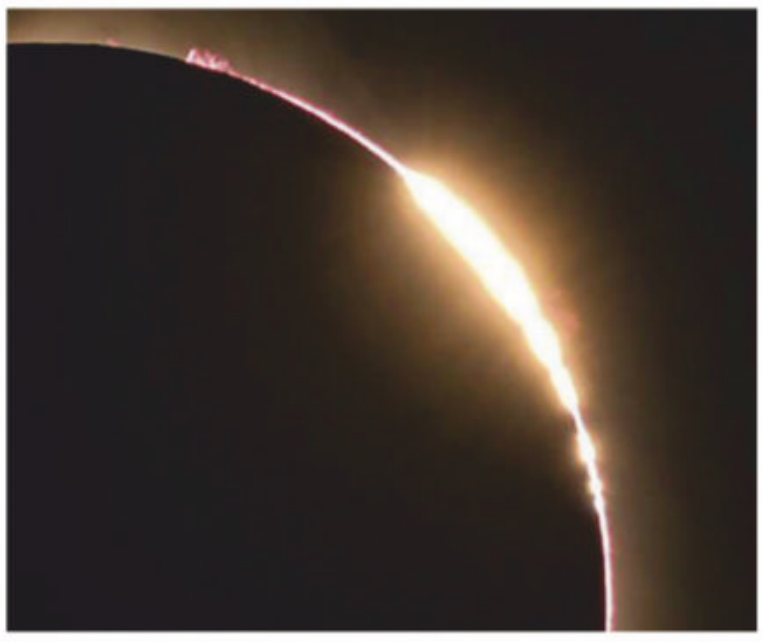
All of that usually applies only to a total solar eclipse. However, June's annular solar eclipse – an event not normally known for anything other than offering a uniform view of a ring around the Moon – will be unusual because of a rare quirk of celestial geometry.

A rare spectacle

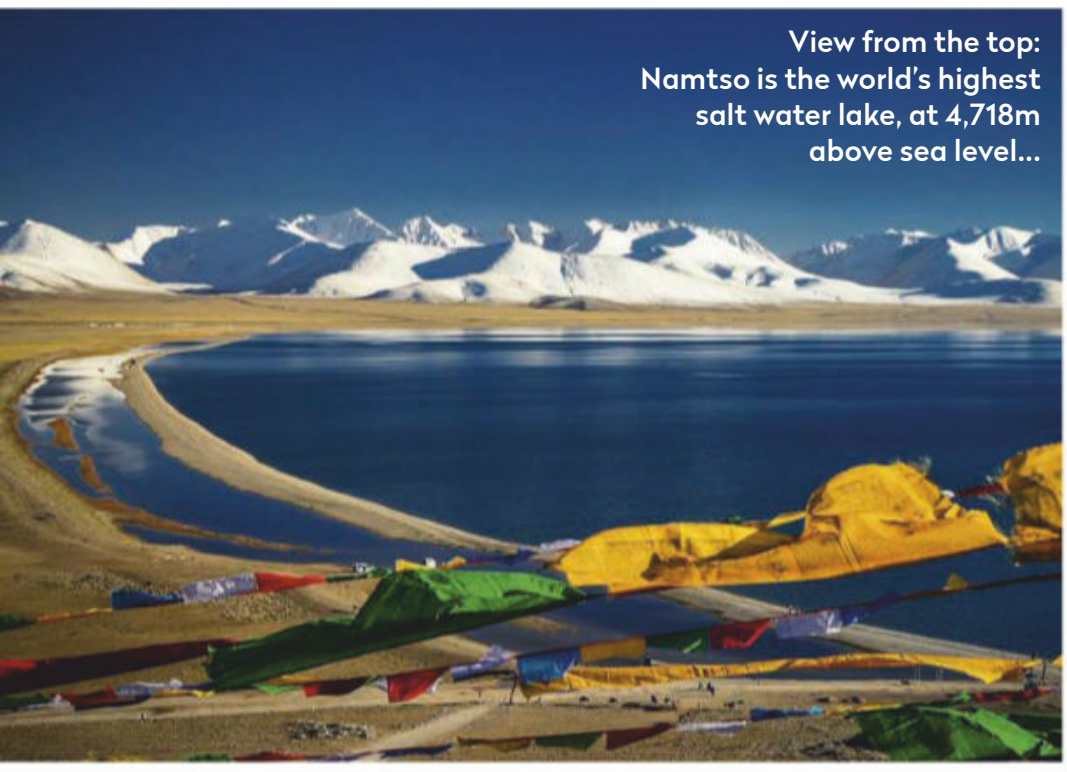
"This eclipse is nearly a total solar eclipse because the Moon is 99.5 per cent the apparent diameter of the Sun," explains Michael Zeiler, an eclipse chaser and cartographer who runs GreatAmericanEclipse.com.

"What is exceptional about this annular solar eclipse is that its very short duration allows for dramatic views of extended Baily's beads and a brief view of the Sun's chromosphere. The interplay of the Moon's mountains and valleys against the narrow annulus ring of the Sun will be a spectacular sight through safe solar filters." ▸

▼ **Light effects: the annular eclipse will be so close to totality that some features of total eclipses may be visible, from the solar corona (below, left), to the solar chromosphere and Baily's beads (right)**



MATTHEW STARLING/ISTOCK/GETTY IMAGES, JOHN FINNEY PHOTOGRAPHY/ISTOCK/GETTY IMAGES X 2



View from the top: Namtso is the world's highest salt water lake, at 4,718m above sea level...

▲ ...and Tibet's incredible night skies make it an ideal location for stargazing

► From an observer's point of view, that is the main difference between a total and an annular solar eclipse; the former allows you to remove protective solar eclipse glasses during the peak of the event, while the latter does not.

The special nature of June's ring of fire means that eclipse-chasers' trips to witness the event were being organised well in advance. They've now been thrown into doubt by the COVID-19 pandemic, but at the time of writing some were still going ahead. One expeditionary trip to see the spectacular event is being led by Dr Tyler Nordgren, an artist, astronomer, night sky ambassador and author of *Sun Moon Earth*. "I'm looking forward to seeing Baily's beads and all those little 'edge effects' as well as an incredibly thin ring, but I don't entirely know what to expect because I've never seen an annular solar eclipse from this kind of altitude," he says.

Nordgren's group of eclipse chasers are planning to watch from close to Namtso, a lake north of Lhasa at a whopping height of 4,718m above sea level. "The impressive thing about Tibet is that we'll be looking through as little atmosphere as possible because it's happening at a time of day when it's very near noon, so the eclipse will occur when it's high overhead."

Embracing the dark side

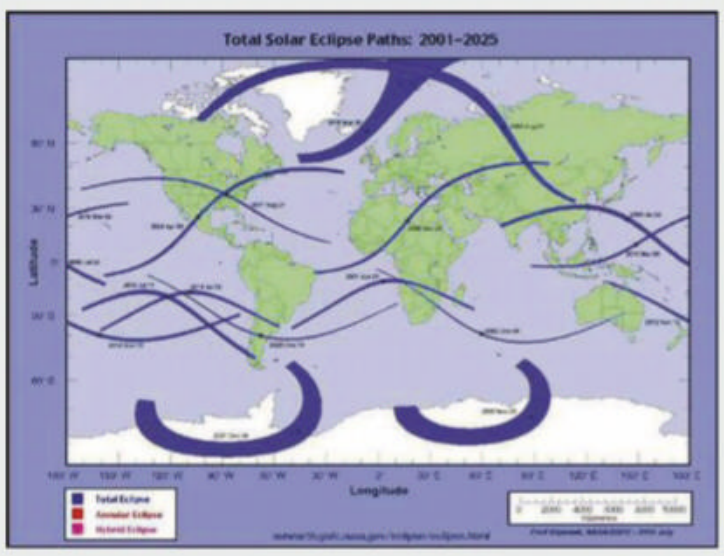
Tibet is also one of the darkest locations on the planet, which makes it the perfect trip for stargazing since all solar eclipses by definition happen at the instance of new Moon. "It should be one of the darkest nights we get to experience anywhere in the world," says Nordgren of this group's plans to camp out the night before the eclipse. "I'm really looking forward to seeing the summer Milky Way from that altitude."

Pinpointing totality

Eclipses are rare, so how do astronomers know when they're coming?

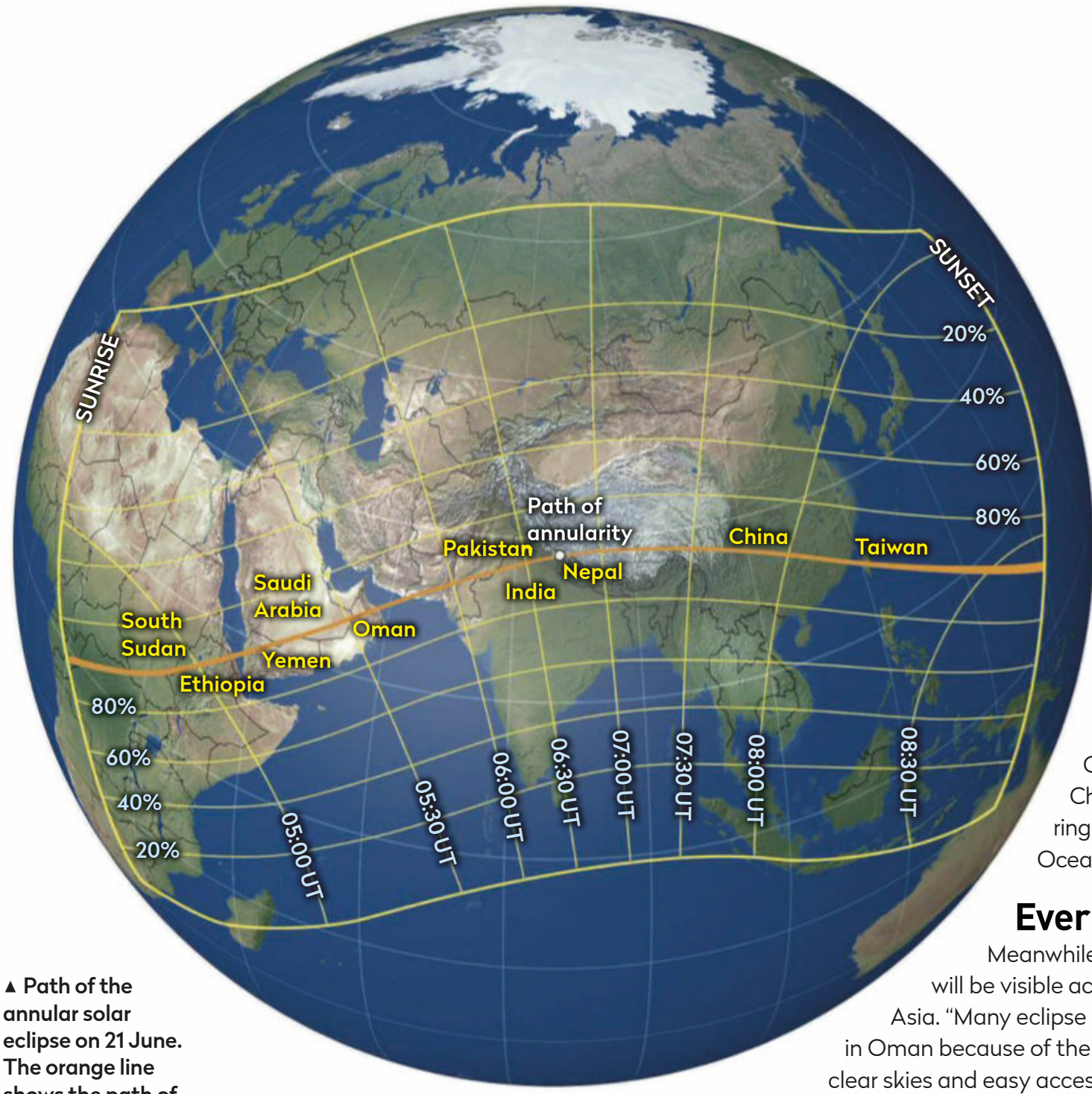
Astronomers can pinpoint the time and location of an eclipse to the millisecond. "What you need is to have an accurate ephemeris, a computer program that can accurately predict where the Sun and Moon are, with respect to Earth," says Fred Espenak, a NASA Scientist Emeritus best known for his work on eclipse predictions, who runs the website **MrEclipse.com**. That means knowing where all three celestial bodies are in three dimensions. "Then you can predict where the Moon shadow is, since it's always pointing away from the Sun."

Figuring out where that shadow is in space, where it's going to be, when it's going to intersect Earth's surface, and how it moves across the surface – all in 3D – is then calculated using spherical trigonometry. "It's all worked out by computer programs, but the techniques for calculating eclipses were worked out several hundred years ago," says Espenak. "Back then they were doing calculations using tables of logs and trig functions. It was done by hand, so it took a huge amount of time to calculate timings for one location." With the right type of software it now takes a fraction of a second.



▲ NASA uses software to accurately track eclipse paths

FRED ESPENAK/NASA/GSFC, YAHUI HUANG/ISTOCK/GETTY IMAGES, YIMING LI/ISTOCK/GETTY IMAGES, MAP BY PAUL WOOTTON



▲ Path of the annular solar eclipse on 21 June. The orange line shows the path of annularity from where a ring of fire will be visible, with a diminishing percentage of the eclipse visible as you move further north or south away from the line

Nordgren and his group will experience a mere 23 seconds of annularity. Why so brief? It's to do with the Moon's elliptical orbit of Earth. "Sometimes it's a little closer to Earth and sometimes it's a little farther away, and that difference of about 10 per cent is the difference between the Moon being able to fully cover the Sun during the eclipse and it being just slightly far enough away that it appears too small to block out the Sun – a perfect alignment," says Nordgren.

"That ring of Sun that's not obscured by the Moon, and still visible during that perfect alignment can be any thickness, and in the case of this eclipse, that alignment happens when the Moon will be just barely too small to cover the Sun, so we'll see an incredibly thin ring." As a consequence of the ring being very thin the perfect alignment is incredibly short. "That's what makes this eclipse so interesting because the shadowed edge of the Moon just grazes the edge of the Sun," says Nordgren.

Despite the scientific rarity of this eclipse, Nordgren will watch it without optical equipment save for solar eclipse glasses. "I really want to avoid looking at an eclipse through a camera or through a telescope because it's a whole world experience," he says, adding that the glow of the sky around the horizon (safe to view with the naked-eye, of course) and the changing hues of the surrounding landscape are just as impactful as studying the 'ring of fire' itself. "My personal feeling is that these eclipses are so much more impressive in a 180° view of the sky," he says.

Although Tibet is favoured for its dramatic view of a very thin annulus, there are other prime locations. The ring of fire is visible at sunrise in the Republic of the Congo and the Democratic Republic of the Congo, then as a higher-in-the-sky spectacle in South Sudan, Ethiopia, Eritrea, Yemen, Oman, Pakistan, India, Tibet, China and Taiwan, with a ring of fire sunset in the Pacific Ocean south of Guam.

Every second counts

Meanwhile, a big partial solar eclipse will be visible across much of Africa and Asia. "Many eclipse chasers will choose Quriyat in Oman because of the near-certain prospect of clear skies and easy access through Muscat," says Zeiler. Another favoured location for organised trips – though largely for those after an eclipse in tourist-friendly surroundings – is Lalibela in Ethiopia, which is famous for its rock-cut monolithic churches.

However, astro-tourism is not what serious eclipse chasing is about. For a total solar eclipse, observers tend to head for the centre of the path of totality to maximise the duration of totality. For expeditionary eclipse chasers, that's not the case with this event.

"For annular eclipses, and especially short duration eclipses, experienced eclipse chasers will choose a location near the north or south limit lines for a very precious few seconds of annularity," says Zeiler. "By choosing such a location, an eclipse chaser will enjoy a stupendous view of the last bits of sunshine rolling about the Moon's disc." With proper photographic gear it will be possible to capture a great view of the Sun's chromosphere, and perhaps a hint of the Sun's corona, though great care will need to be taken. "This eclipse will be so fleeting that observers will bring several dedicated telescopes and long lenses to record the spectacular evolution of this brief eclipse," says Zeiler.

Whether anyone gets to travel to see the super-slim ring of fire remains to be seen, but a huge swathe of the planet will, come June, be scrambling for solar eclipse glasses to take a peek. It promises to be a huge event, which shouldn't be taken for granted; the next one – on 10 June 2021 – occurs in ultra-remote regions of Canada, Greenland and Russia. More proof that if you like your travel convenient and comfortable, think carefully before becoming an eclipse chaser.

Jamie Carter is a science journalist and editor of WhenisTheNextEclipse.com

WATCH ONLINE

Visit **www.skyatnightmagazine.com** to watch a live stream of the eclipse.

The fundamentals of astronomy for beginners

EXPLAINER

What's in a Moon name?

Each month's full Moon has a well-known name, but this year they get really mixed up

Photo opportunity: a rising full Moon can be a breathtaking sight to witness

ALEX_MACHINEGUN/ISTOCK/GETTY IMAGES, ANAGRAMM/ISTOCK/GETTY IMAGES

Today everyone's familiar with the popular, informal names given to full Moons – there's a different one for each month – June's full Moon is called the Strawberry Moon. But there's a problem with these names, because our calendar of 12 months isn't in sync with the lunar cycle – and in 2020 it really comes home to roost.

For the most part our calendar and the lunar cycle are in sync and we get a full Moon every month, but sometimes there are two full Moons in one month and possibly none in another. And this mismatch gets more complicated because one full Moon does have a fixed definition – the Harvest Moon. These problems are illustrated by this year's full Moons (see list, right) and the way the popular names fall.

2020's popular full Moon names

Date	Title
10 January	Wolf Moon
9 February	Snow Moon
9 March	Worm Moon
8 April	Pink Moon
7 May	Flower Moon
5 June	Strawberry Moon
5 July	Buck Moon
3 August	Sturgeon Moon
2 September	?
1 October	Harvest Moon
31 October	Hunter's Moon
30 November	Beaver Moon
30 December	Cold Moon

▲ **True blue: the only time the Moon will actually look blue is during daylight**

Most of the names fit just fine, but there's one gap and it's not easy to fill – that's the Harvest Moon. The Harvest Moon is defined as the closest full Moon to the Northern Hemisphere's autumn equinox, and this year, the full Moon on 1 October gets the title because it occurs just nine days after the equinox. But search online for 'Harvest Moon 2020' and you'll see many references to it being the 2 September full Moon, which is 20 days earlier than the autumn equinox; this is simply because of where it falls in the informal naming sequence.

So how is this gap in popular full Moon names in 2020 to be filled? One compromise would be to call it the Corn or Barley Moon, names sometimes used for the September full Moon, but ignored when the Harvest Moon occurs in September.

Once in a Blue Moon?

The Harvest Moon mix-up also raises questions about another lunar term around which there is an element of confusion, the Blue Moon.

By some definitions, the full Moon on 31 October is a Blue Moon as it's the second full Moon in the same month. This definition has become a popular one, but it's based on a misinterpretation which originated in a 1946 edition of *Sky & Telescope Magazine* and became widespread in the 1980s after it was used in a popular radio show and the board game *Trivial Pursuit*. The original definition of a Blue Moon is the third full Moon in a season which contains four full Moons. Here, the seasons are defined as the time between winter solstice, spring equinox, summer solstice and vernal equinox. The list below shows how things break down for 2020.

Astronomical seasons in 2020

Season 1

22 Dec 2019 – 20 Mar 2020. Contains 3 full Moons: 10 Jan, 9 Feb and 9 Mar

Season 2

20 Mar 2020 – 20 Jun 2020. Contains 3 full Moons: 8 Apr, 7 May and 5 Jun

Season 3

20 Jun 20 – 22 Sep 2020. Contains 3 full Moons: 5 Jul, 3 Aug and 2 Sep

Season 4

22 Sep 2020 – 21 Dec 2020. Contains 3 full Moons: 1 Oct, 31 Oct and 30 Nov

The full Moon which occurs on 30 December 2020 technically belongs to the new winter season for 2021 because it falls after the Northern Hemisphere's winter solstice on 21 December 2020. So rather eloquently, if you follow the original definition, there is no Blue Moon in 2020 because each season only has three full Moons.

So with no formal definitions for full Moon names, except the Harvest Moon, and with the mistaken definition of Blue Moon, the popular full Moon naming system is showing its cracks this year. But there is a solution that fixes the names of the full Moons and the definition of a Blue Moon and marries them together. This is an antique naming system, that was originally used in old almanacs of the British Isles. These poetic names (see list, below) are attributed by season.

Traditional full Moon names

Winter 2020 season

10 January: Moon after Yule
9 February: Wolf Moon
9 March: Lenten Moon

Spring 2020 season

8 April: Egg Moon
7 May: Milk Moon
5 June: Flower Moon

Summer 2020 season

5 July: Hay Moon
3 August: Grain Moon
2 September: Fruit Moon

Autumn 2020 season

1 October: Harvest Moon
31 October: Hunter's Moon
30 November: Moon before Yule

Winter 2021 season

30 December: Moon after Yule
28 January: Wolf Moon
27 February: Lenten Moon

The waxing and waning appearance of the Moon is a constant in our skies and the appearance of the full Moon can be a mixed blessing. Its bright light makes it much harder to see the stars beyond, but it does have a beauty all of its own – something easy to appreciate if you take the time to look. Using informal or formal names helps us appreciate the lunar cycle, and it's interesting to see how the naming systems had the mismatch between our calendar and the lunar cycle covered. Maybe this is a better way to go in the future.

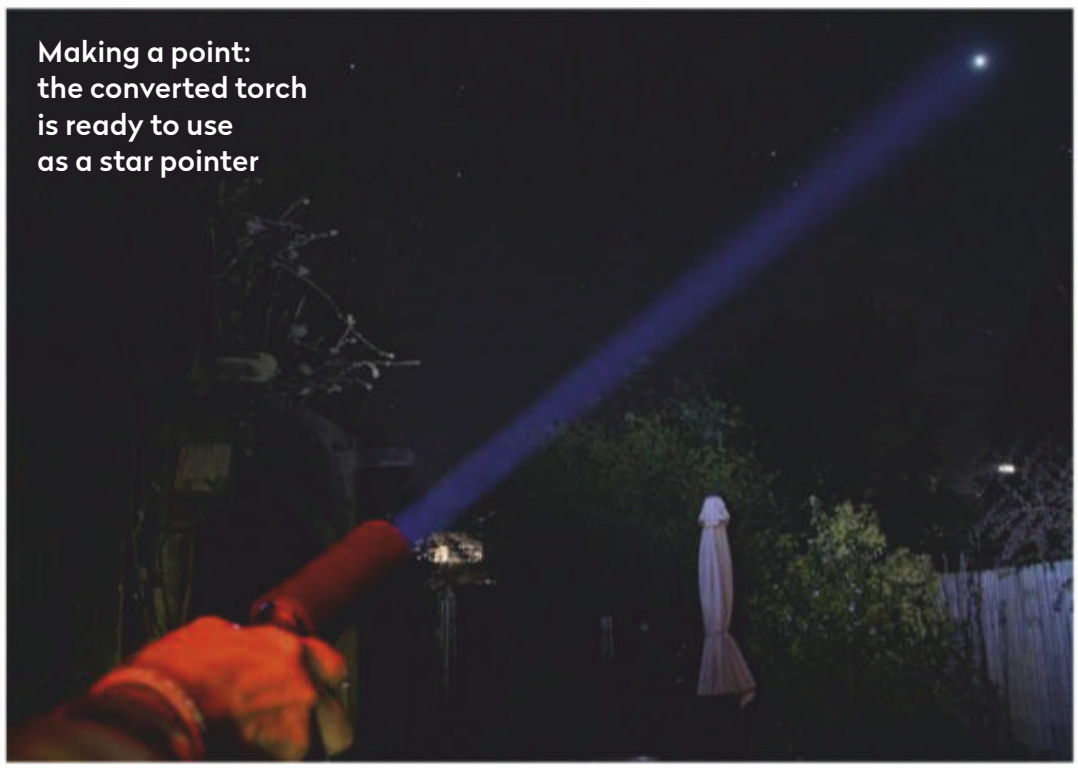
Expert astrophotographer **Pete Lawrence** presents *The Sky at Night* on BBC TV and writes the magazine's monthly Sky Guide, including our regular Moonwatch section

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Make your own LED torch-pointer

Customise a focusable torch so it will produce a narrow beam of light



Making a point: the converted torch is ready to use as a star pointer

Green lasers are very useful as star pointers when we show people around the sky at star parties and outreach observing events. But there has been concern about their use, especially in built-up areas and near airports, with some astronomical societies banning them at events. The advent of inexpensive but powerful compact LED torches with adjustable focus gives us an opportunity to make a safer alternative.

Although these LED torches are focusable, they do not produce the narrow pencil of light that makes a good pointer. To achieve that we need to extend the torch and replace the existing lens with one of a greater focal length.

You will need a torch with a bright LED because our conversion will result in a beam that is dim: we used one with a specified luminous flux of 1,000 lumens. We'd recommend that you read the reviews when buying online as some of the sellers' brightness claims are rather optimistic. If you get a torch that gives you the option of AAA or 18650 lithium-ion batteries, use the 18650 as this will give you a brighter beam, last longer, and can be recharged. Adjustable focus makes the accuracy with which you must cut the tube and assemble the parts far less critical, because you can use the adjustment to compensate for any imprecision. We used an IceFire T70 torch with an XML-T6 LED as this met all the necessary criteria for this project, but you can search around for a similar model.

You will need to replace the torch's lens, so the lens cell should be one that unscrews. Our existing lens had a focal length of 25mm and we needed a replacement with a focal length about four times as great. We also needed to extend the torch with a length of tube. To cement the parts together we used mouldable glue, which sets with a pliable rubbery consistency and fills gaps, so the tube doesn't have to fit tightly. Measure the diameter of your torch and if you don't already have a tube, use online pipe data tables (eg, **bit.ly/2UigVRL**) to find a suitable product. Avoid polyethylene tube as mouldable glue won't adhere to it.

Your replacement lens needs to be smaller than the inside diameter of the pipe, but the larger it is, the brighter your beam will be, so use as large a lens as you can. The exact focal length is not critical; ours is 100mm, but a 20 per cent difference either way will still be satisfactory. For the same diameter lens, a longer focal length will give you a narrower, but less bright, beam and will, of course, create a more unwieldy result.

We obtained our lens from a damaged eyepiece which, along with used budget eyepieces, are a good source of lenses. If you have to purchase a lens, note that optical quality is not important for this purpose, so even a cheap plastic one will give you a clear enough beam to guide people around the sky.

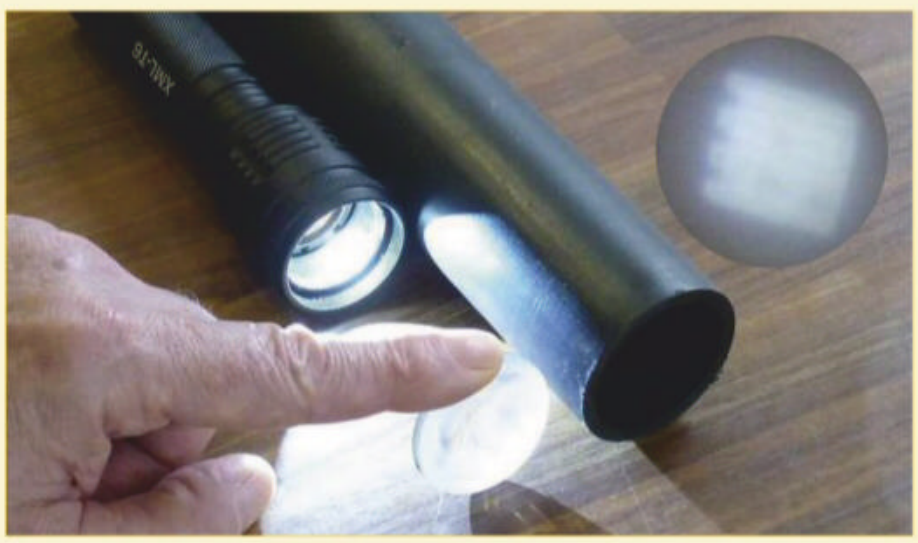
Steve Tonkin is a binocular observer who takes part in projects with The Astronomical Unit

What you'll need

- A bright, adjustable-focus compact LED torch with a removable lens.
- A plastic tube with a length equal to the focal length of the lens plus about 30mm. The tube needs an inside diameter slightly greater than the outside diameter of the torch.
- A converging lens with a focal length of 100mm to fit inside the tube.
- Mouldable glue to make the lens cell and to cement the tube to the torch.
- A saw to cut the tube, a file to deburr the cut end, an abrasive pad to finish smoothing the cut end, and a dowel to shape the inside circumference of the lens cell.

ALL PICTURES: STEPHEN TONKIN

Step by step



Step 1

You can establish the required length of the tube by setting the torch to half its focal range, 5m or more from a blank wall, and holding the lens in front of it to give a sharp image of the LED on the wall (shown inset).

Step 2

Mark the tube at the required length. Wrap a sheet of paper around the tube at the cutting mark, then mark around the edge of the paper to give a cutting line that is at right angles to the length of the tube.

Step 3

Use a sharp saw to cut the pipe. An ordinary handsaw will suffice for plastic pipe but, if you are using metal pipe, you will need a hacksaw with a blade of 24 teeth per inch or finer. Use a file to deburr the cut edge.

Step 4

Make the inner part of the lens cell with some mouldable glue. You can use the lens itself to push it to the correct position in the pipe and shape the front of the cell with a wet dowel to obtain a smooth inside circumference.

Step 5

Clean the lens and put it into place, then make a thin sausage of mouldable glue. Carefully feed this around the inside of the tube, in contact with the lens, then smooth it into place so that the glue firmly adheres to the tube.

Step 6

Set the torch to mid-focus again and slip the tube over it. Note the position for best focus, then use mouldable glue to cement the tube into place. Leave it overnight for the glue to set, then smooth any rough edges with the abrasive pad.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

A lunar occultation of Venus

Catch a special pairing of the Moon and Venus, rising close together under daylight conditions

The Moon's angular diameter in our sky is about half a degree. Hold your little finger up at arm's length and this is approximately 1° wide. You could hide two full Moons side by side behind it.

With a huge sky to wander around in, it's not surprising that the tiny Moon rarely hides the planets. Actually, 'huge sky' is misleading because the Moon's apparent movement is restricted to a 10°–wide corridor, centred on the ecliptic. The ecliptic is a great circle that represents the plane of Earth's orbit and the apparent path of the Sun against the stars over a year.

All of the main planets and the Moon have orbits aligned to the ecliptic. Each has a tilt which means it travels in its own narrow corridor around the ecliptic. The Moon's orbit is tilted by a mean inclination of 5.15°, varying between 4.99–5.30°, hence the 10° corridor.

Even given this restricted movement, occultation encounters between the Moon and planets are infrequent enough to make them special, but on 19 June the Moon will pass in front of Venus in daylight.

▲ On 19 June the occultation of Venus and the Moon begins around 08:38 BST (07:38 UT) and lasts around 65 minutes

ALL PICTURES: PETE LAWRENCE

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

The easiest way to locate the Moon and Venus on the morning of 19 June is to watch them rise above the east-northeast horizon before sunrise. They appear an hour before sunrise. From the UK's centre, both appear around 03:50 BST (02:50 UT) as the twilight brightens.

Keep on target

Using an equatorially mounted scope, centre on Venus and stay with it as the sky brightens. Venus and the Moon should remain easy to see once you're locked on. As they rise, their separation will be 2.7°, which reduces rapidly. At sunrise, 04:50 BST (03:50 UT), Venus is around 2.2° from the Moon's centre.

When they are due east, around 06:45 BST (05:45 UT), they will be 23° up and appear 1.2° apart. At 08:15 BST (07:15 UT) the distance from Venus to the Moon's centre is equivalent to the Moon's apparent diameter, about half a degree. If your imaging setup allows you to capture the Moon in one go, you should be able to grab both objects in the same field of view.

At 08:30 BST (07:30 UT) Venus appears close to the southwest portion of the 3%-lit waning lunar crescent. Here is an amazing opportunity to photograph two crescents at the same time, Venus showing as a 7%-lit crescent 1/35th the apparent diameter of the Moon.

The Moon's bright edge starts covering Venus at 08:38 BST (07:38 UT), taking two minutes to hide its disc. The time of the occultation varies slightly with location so it pays to ensure you watch or image several minutes before the stated time. Reappearance from behind the Moon begins around 09:43 BST (08:43 UT).

Imaging this event is relatively straightforward given clear skies. Preparation is everything. If you're successful, the final result will show two perfect crescents against a blue sky – a priceless image if done right.

Recommended equipment: camera with a lens of focal length 600mm (APS-C) or 1,000mm (full frame)

✉ Send your images to:
gallery@skyatnightmagazine.com

Step by step

STEP 1

Decide how to image the event. A wide-field setup allows you to grab the entire lunar crescent with a small Venus. A scope with a focal length around 1,000mm is ideal. A lower focal length works too but the Venusian crescent may become lost, while a longer focal length shows the crescent but is trickier to work with.

STEP 2

As described in the main text, attempt to centre on Venus as early as conditions allow. A driven, correctly aligned equatorial mount is highly recommended to keep the planet in view without the need for manual adjustment. Do checks to make sure Venus is in the field of view to avoid a last-minute panic if the drive stops working.

STEP 3

Once Venus is in view, focus on it as accurately as you can. If you do this well before the occultation, make sure you re-check the focus as the heat of the day can cause it to drift out. If you're planning to use a high-frame-rate planetary camera consider using an infrared pass filter. This will darken a blue sky and improve

STEP 4

If you plan to image using a DSLR, the bright scene means a low ISO can be used. This will improve tonal quality and keep noise down. Stopping the lens aperture down will increase your depth of focus allowing you a degree of error on your focus setting. Higher f-numbers may reveal dust spots on your camera's sensor though.

STEP 5

A short exposure will work best. Take a test shot and examine the histogram. Ideally, the main data peak should lie between the two graph ends. Venus appears bright and virtually white which makes getting an ideal histogram tricky. Just ensure the lunar crescent doesn't over-expose to pure white.

STEP 6

If you're using a high-frame-rate planetary camera, ensure you're set for a high frame rate and image the planet in short bursts of less than 4 seconds during the main occultation phase. This will allow you to maintain a sharp planet during the registration-stacking processing as it gets covered by the edge of the Moon.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Using Photoshop to draw out the detail of a galaxy

By adjusting RGB channels a featureless raw image of M31 can be transformed

Most astrophotographers start out using a DSLR camera. These versatile cameras produce detailed deep-sky images, but while narrowband data from mono cameras creates clear contrasting colours, DSLR data can be complex to process. This is because of the way light is distributed onto the camera sensor. Narrowband filters allow separate processing of Red, Green and Blue (RGB) channels, whereas DSLRs and one-shot colour cameras pick up the wavelengths of light simultaneously. The sensor distributes this light via its own RGB filter arrangement, the Bayer matrix. If RGB is managed carefully, you can bring out additional details from DSLR images while maintaining a natural appearance.

We used an image of the Andromeda Galaxy, M31, to demonstrate RGB processing functions in Adobe Photoshop. RGB control is done via three main settings: 'Levels', 'Selective Colour' and 'Hues/Saturation'. Each of these are in the 'Adjustments' menu, click 'Image > Adjustments'. With these functions, you can align and alter colour channels. If not done in gradual stages, you risk making your process too severe. We recommend performing more than one colour 'stretch' at stages throughout processing, in order to add gradual colour developments.

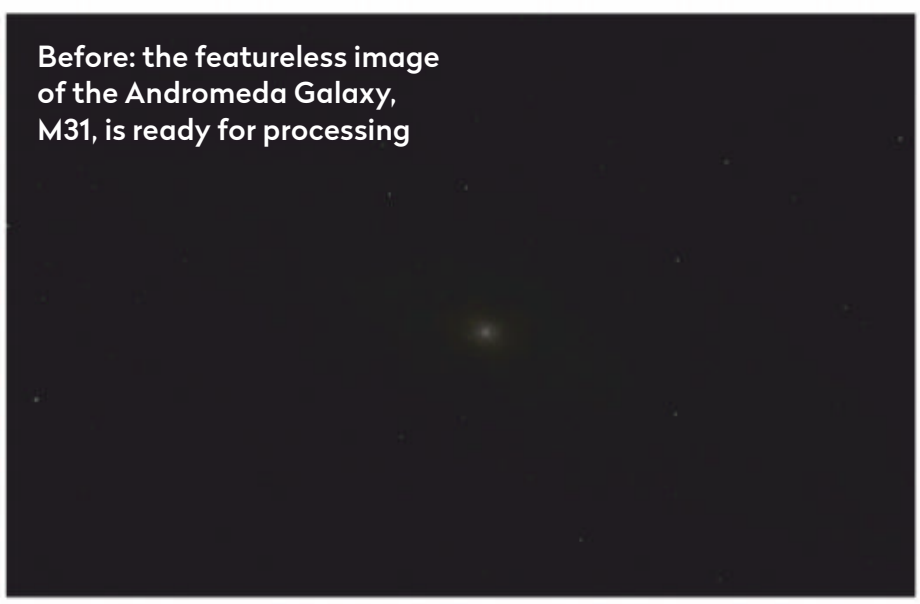
Charlotte Daniels is an astronomer, journalist and aircraft broker

After stacking files in Sequator, we open the TIFF file in Photoshop: click 'File > Open' and crop the image by clicking 'Image > Crop'. This is an important step before the main process. When stacking images over several hours – or from two different nights – your image-alignment can shift, causing uneven colours around the edges. By cropping these out beforehand, we prevent anomalies affecting the colour balance.

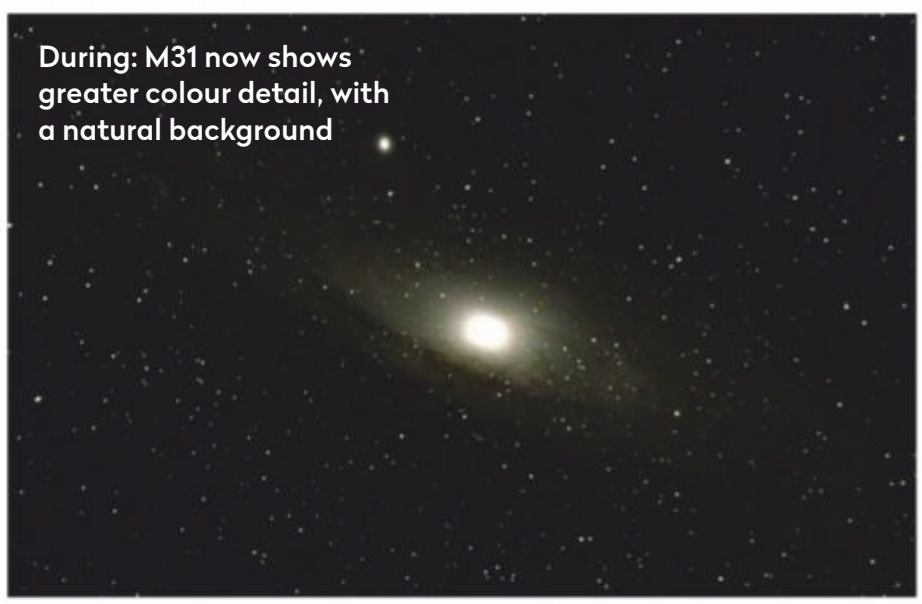
Fine adjustments

Our image is ready for processing but at this stage it looks dull (see image, below, left). We suggest starting with 'Levels' – click 'Image > Adjustment > Levels'. This enables a manual colour balance to ensure you haven't got one dominant colour overtaking the process. This can vary between cameras: for example, a modified DSLR will have a dominant red channel.

The 'Properties' tab in 'Levels' ('Red' box) allows you to select each of the RGB channels separately, starting with 'Red' (see Screenshot 1). Make sure the 'Histogram' channel on the right-hand side is set to 'Colours' rather than 'RGB' so that you can monitor changes. Move the sliders so that the left-most dark tab is touching the edge of the 'Red' histogram. Next, drag the right-most white tab (which will also move the inner grey tab) until the grey tab is near the right-hand side of the histogram (see Screenshot 2).

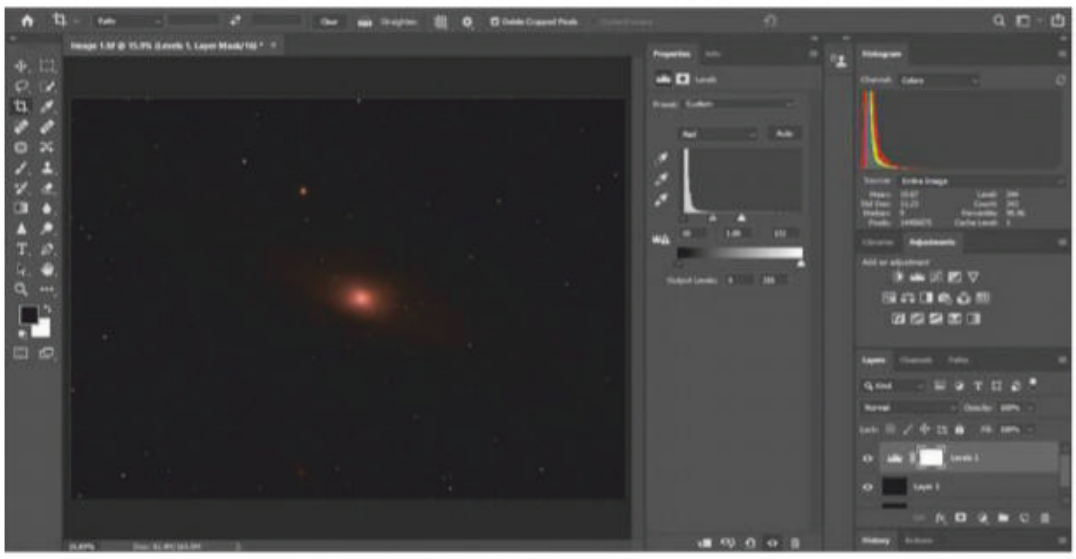


Before: the featureless image of the Andromeda Galaxy, M31, is ready for processing



During: M31 now shows greater colour detail, with a natural background

ALL PICTURES: CHARLOTTE DANIELS



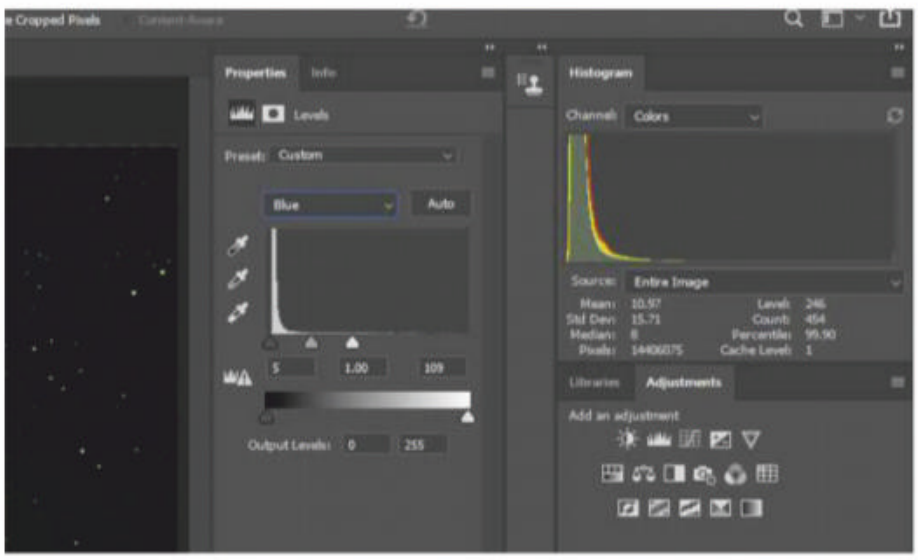
▲ Screenshot 1: select each RGB channel in the 'Properties' tab in 'Levels'

3 QUICK TIPS

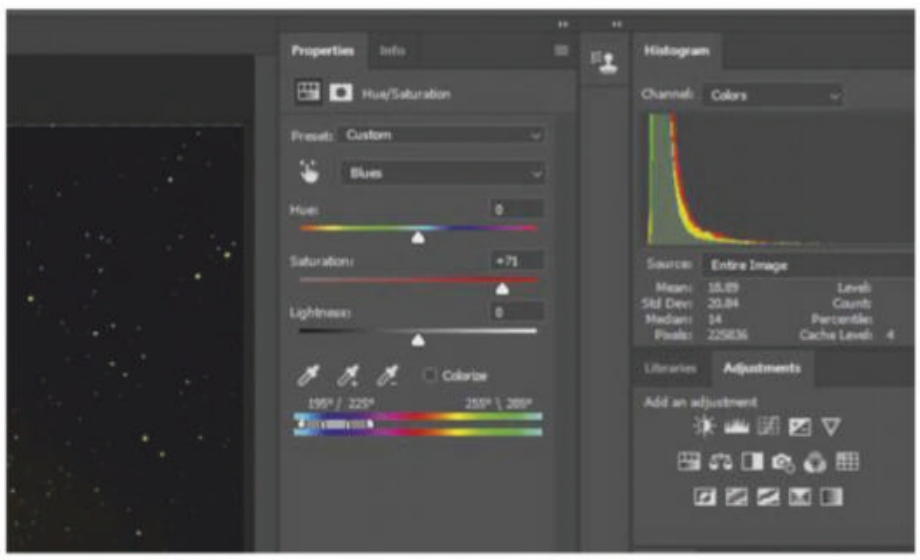
1. Make small changes. You don't want to overstretch the data and lose details around the core.

2. Every time you make an adjustment, start a new layer to build on your progress.

3. Change blending mode to 'Colour' when adjusting 'Selective Colour' or 'Hue/Saturation' – find it in the drop-down menu above 'Layers'.



▲ Screenshot 2: adjustments can be made to the 'Histogram' channel



▲ Screenshot 3: boost colours with the hand-tool in 'Hue/Saturation'

Repeat for 'Green' and 'Blue' channels then right-click the layer and select 'Merge Down'. We are aiming for a 'Histogram' which shows all colours contained evenly within the data. Hold down 'Shift, Ctrl, Alt, N and E' to create a new layer that retains these changes.

We repeat this process again. For this second attempt the histogram for each channel is wider, allowing us to make finer adjustments. The M31 image (see opposite, below right) is showing greater colour detail, and the background looks natural. Again, use 'Merge Down' and create a new layer. As the central area looks a little green, we can adjust this in 'Selective Colour' and 'Hue/Saturation'.

Both settings are also in the 'Adjustments' menu (click 'Image > Adjustments'). When performing tonal or saturation adjustments, it's worth changing the blending mode (second drop-down menu in the 'Layers' window) from 'Normal' to 'Colour'. This allows colour adjustment without altering image brightness.

'Selective Colour' allows you to modify the tones of each colour by altering 'Cyan', 'Magenta', 'Yellow' and 'Black' (CMYB) levels. We use the hand-tool in the 'Hue/Saturation' properties window to click on areas we think need a colour boost (see Screenshot 3). For M31 we concentrate on red, yellow saturations round the core, and blues and cyans round the outer edges. Create a new layer for each adjustment. You can use the 'Opacity' slider (situated above 'Layers') to control the strength of saturation adjustments for each layer.

Our final image (see right) has undergone the above colour adjustments. In order to extract its full potential, we can use other provisions from the 'Adjustments' menu, including 'Brightness/Contrast' and 'Curves'. We also suggest applying masks to protect or highlight various regions and using noise reduction techniques to remove unwanted artefacts.

One of the key ingredients for astrophotography, however, is good colours, and the above Photoshop settings will help you achieve this.

After: the image of M31 following colour adjustments

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

PHOTO OF THE MONTH

△ Pinwheel Galaxy, M101

James Harrison, Witney, Oxfordshire, March 2020

James says: "I captured this in my back garden near Witney, where we have skies that measure 4 on the Bortle scale (a nine-point scale that measures the night sky's brightness where 1 is the darkest). I've always liked the Pinwheel Galaxy, with its nebulous edges and complex core, and was glad to to it justice with one of the largest datasets I've gathered on a single target."

Equipment: ZWO ASI 183MM Pro mono camera, Sky-Watcher Explorer 200P Newtonian reflector, Sky-Watcher EQ6-R Pro mount
Exposure: 6 hours RGB, 1 hour Ha
Software: PixInsight

James's top tips: "Accurate focus is key for detailed galaxy images, so take your time and refocus regularly as temperatures change. I mostly used five-minute long exposures as a balance between getting a good signal-to-noise ratio, not overexposing the core of the galaxy and avoiding blur due to guiding and mount motion. Experiment to see what works best on your setup. Spend time experimenting with different guide tools and settings – and avoid windy nights if you're using a large telescope like a Newtonian!"

Comet ATLAS ▷

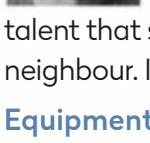
Kevin Reid, St Ives, Cornwall, 28 March 2020

Kevin says: "Since its discovery in December last year, Comet ATLAS has brightened significantly and I thought it would be fun to track its progress. Its head was too faint to track on to, so the challenge was to keep the frames short enough to accurately represent the moving comet, but long enough to capture the faint developing tail."

Equipment: CQSI 683 mono CCD camera, Orion AG12 Newtonian, Losmandy Titan mount **Exposure:** L 9 x 3–5', RGB 5 x 3' each **Software:** PixInsight, MaxIm DL

▽ Mare Crisium

Ian McCrea, Leyland, Lancashire, 27 March 2020



Ian says: "As the Moon had started its early evening appearance, I was excited to try my new scope. I previously tried widefield deep-sky imaging, but I haven't got the patience or talent that so many others have, so I opted for our closest neighbour. It's my first shot at the Moon and I'm hooked."

Equipment: ZWO ASI 224MC colour camera, Sky-Watcher Explorer 150PL Newtonian reflector, Sky-Watcher HEQ5 Pro mount **Exposure:** 1,000 frames captured, best 15% stacked **Software:** PIPP, AutoStakkert!, Photoshop

△ Moon mountain

Melanie Thorne, The Gullet, Antarctica, 10 March 2020

Melanie says: "From my cabin it looked like a lovely sunrise, so I rushed outside with my camera while almost everyone else was asleep. The sky was all pink and purple and it was so tranquil and peaceful. I was so glad I'd dragged myself out of a cosy bed."

Equipment: Nikon D7100 DSLR camera, Nikon 70–300mm lens
Exposure: ISO 320, f/8 **Software:** Lightroom

△ Carina Nebula

Newton Cesar Florencio, Londrina, Brazil, 22 and 24 March 2020

Newton says: "Here in the Southern Hemisphere in spring (our autumn), the Carina Nebula appears quite high in the sky by about midnight. To capture it I needed two nights at the end of March. This image was taken from the city of Londrina (Bortle 8) at the amateur observatory Draco Australis."

Equipment: QHYCCD QHY9S-M camera, Canon 200mm lens, Sky-Watcher AZ-EQ5 mount **Exposure:** Ha 12 x 300", OIII 12 x 300" **Software:** APT, Fitswork, Photoshop

◁ Venus and the Pleiades

Paul Peter Pelle, Szombathely, Hungary, 4 April 2020

Paul says: "I took this image of Venus visiting the Pleiades in April, just as Earth was about to say goodbye to the 'Seven Sisters' for summer. It will be eight years before we see another conjunction this close."

Equipment: Canon EOS 6D DSLR, Sky-Watcher Star Adventurer mount **Exposure:** 31 x 30" **Software:** Backyard, DeepSkyStacker, Photoshop

△ Eyes of Clavius

David Ettie, Washington, Tyne and Wear, 1 April 2020

David says: "I took this image of the Moon from my garden observatory in Tyne and Wear. The 'Eyes of Clavius' are formed when light from the rising Sun just catches the rims of Clavius C and D."

Equipment: Altair Astro Hypercam 183C colour camera, Celestron 9.25" SCT, Sky-Watcher HEQ5 Pro mount **Exposure:** 6,000 frames **Software:** AutoStakkert!, RegiStax, Photoshop

△ ISS pass

Cian O'Regan, Glandore, Ireland, 26 March 2020

Cian says: "This shows the International Space Station passing over the Drombeg Stone Circle, 17 standing stones dating from 153 BC–AD 127. This image captures two engineering marvels built 2,000 years apart!"

Equipment: Nikon D3300 DSLR, Tokina SD 11–16mm f/2.8 lens **Exposure:** ISO 1600, 5 x 15" **Software:** Lightroom, Startrails

◁ Needle Galaxy

Chris Platkiw, Derbyshire, 23–25 March 2020

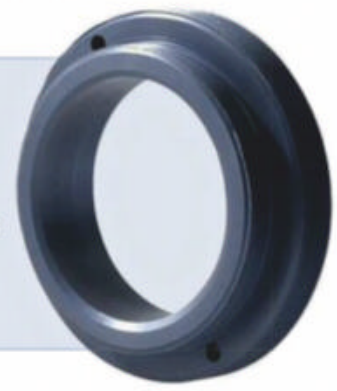
Chris says: "The Needle Galaxy is my favourite. I saw it in the 2017 Astronomy Photographer of the Year album and it captured my imagination. A combination of timing with a new Moon, a run of clear nights and reduced air traffic helped me get the detail."

Equipment: ZWO ASI 178MC colour camera, Celestron C8 Schmidt-Cassegrain, Sky-Watcher HEQ5 Pro mount **Exposure:** 12.5h total **Software:** PixInsight, Photoshop

ENTER TO WIN A PRIZE. HERE'S HOW:

Whether you're a seasoned astro-photographer or a beginner, we'd love to see your images. Email them to contactus@skyatnightmagazine.com. Ts&Cs: www.immediate.co.uk/terms-and-conditions

We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a finder–guider adaptor, which connects T-thread guide cameras from ZWO, Orion and others to 9 x 50 standard finders from Sky-Watcher. The accessory comes with full instructions and support. www.modernastronomy.com • 020 8763 9953



EXCEPTIONAL, RISK-FREE OFFER

DON'T MISS AN ISSUE!
FREE DELIVERY TO YOUR HOME

We want to make it as easy as possible for our readers to get their copy of *BBC Sky at Night Magazine* at this difficult time, so we have devised a unique offer for you that we hope will help.

For the next 3 months, we will deliver your copy of *BBC Sky at Night Magazine* direct to your door, for only £14.03 – a saving of 15% on the usual shop price and with no delivery charge*. This offer is risk-free and doesn't require starting a Direct Debit. It simply requires a one-off payment, and if you decide that you do want to cancel before the 3rd issue, we will refund you for any remaining issues**. It's a simple, no-strings way to make sure you get your copy if you are unable to get to the shops. Just order on the link below or call our hotline.

We also regularly run longer term subscription offers, which are only available by Direct Debit. If this suits you better, you will find an offer on pages 24-25 with our current Direct Debit offer on it.

TO RECEIVE 3 ISSUES OF *BBC SKY AT NIGHT MAGAZINE* TO YOUR HOME:

Order online: www.buysubscriptions.com/SKspring3

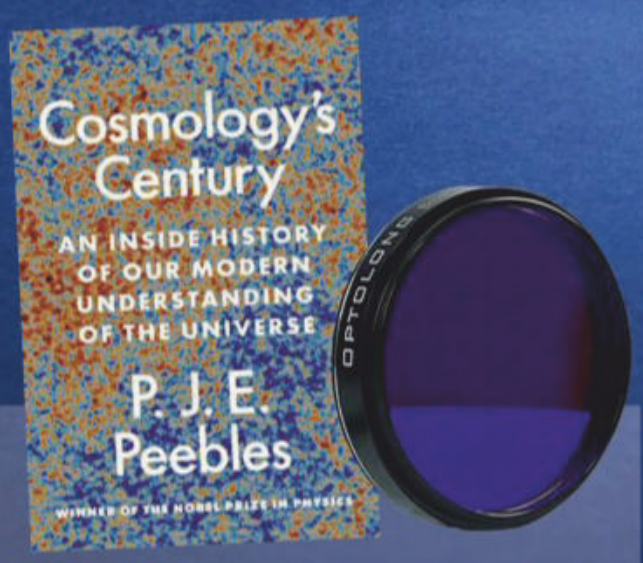
Or call us on 03330 162 119† and quote code SPR3MPG, *BBC Sky at Night Magazine*

Terms and conditions: *Pay just £14.03 for 3 issues (saving 15% on the shop price). Offer ends 30 June 2020 and is open to UK delivery addresses only. Overseas rates are available. **You may cancel at any time and receive a full refund on any outstanding issues. †UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages, call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8am-6pm and Sat 9am-1pm.

The best in equipment, accessories and books each month

REVIEWS

Find out more about how we test equipment at
www.skyatnightmagazine.com/scoring-categories



PLUS: Books on understanding the Universe, Hubble's legacy and a roundup of must-have astronomy gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★½ Very good
★★★½★ Good ★★½★★ Average ★½★★★ Poor/avoid

@THESHED/PHOTOSTUDIO

FIRST LIGHT

Canon EOS Ra astrophotography camera

A full-frame mirrorless camera that will enrich your astro-imaging experience

WORDS: CHRIS GRIMMER & CHARLOTTE DANIELS

VITAL STATS

- **Price** £2,599.99 (body only)
- **Sensor** 36 x 24mm 30.3MP CMOS sensor
- **ISO range** 100-40,000
- **Live View** magnify image 5x, 10x or 30x for manual focusing
- **Size** 135.8 x 98.3 x 84.8mm
- **Weight** 580g (660g with battery and memory card)
- **Supplier** Canon
- **Tel** +44 (0)207 660 0186
- **https://store.canon.co.uk**

The Canon Ra is the first full-frame mirrorless camera from Canon to come 'astro-adapted', with enhanced infrared (IR) sensitivity. Although DSLR versions have been released previously, these have been mirrored, with cropped sensors. The Ra's 30.3 MP CMOS sensor might not be groundbreaking, but the infrared filter adjustment and full-frame format are big news for astrophotographers.

While the Ra might be lighter than other cameras due to its mirrorless design, it has a solid, reliable feel. It also retains DSLR attributes such as a viewfinder and vari-angle LCD touchscreen. One of the first things we noticed is that the Ra works in a similar way to a regular Canon DSLR, albeit a high-performing one. This makes it easy to get to know the camera, both for a novice or an experienced astrophotographer who is used to Canon cameras. It takes the new RF lenses while EF and EF-S lenses can be attached using the optional extras: including an EF to EOS R adaptor, EF to EOS R adaptor with control ring, or EF to EOS R drop-in filter adaptor. Note that EF-M lenses are not compatible.

Familiar territory

Operating the Ra is instinctive; if you've ever used a Canon camera before it feels like an old friend. The standard go-to buttons are where Canon users would expect them, including Live View mode, playback and settings. These are all logically placed for finding in the dark. Connection to a telescope is achieved using a Canon T-ring and EF to EOS R adaptor, while Bulb mode is accessed in the mode-wheel to enable long exposures. To focus, we can't sing the praises of the Ra's Live View highly enough – using the 30x magnification setting we were able to zoom in and count the four Trapezium stars of the Orion Nebula. This level of detail makes the Ra enjoyable and interesting to use.

The Ra's Wi-Fi and Bluetooth provisions allow you to connect it with a smart device using the downloadable Canon Connect app. In terms of ports, the Ra comes with the connections you'd expect, including HDMI Out, Microphone In and a remote-control terminal. ▸

Seeing infrared

The Canon Ra benefits from a modified infrared (IR) filter, allowing it greater sensitivity for detecting delicate nebulosity over non-modified full-frame or cropped sensor DSLRs. While standard DSLRs register light up to a wavelength of 650 nanometres due to an IR-cut filter, astrophotography cameras need to go further for optimal performance, especially on nebulae. Hydrogen, the primary gas in emission nebulae, emits hydrogen-alpha (Ha) light at around 656nm, so we need our camera sensors to detect a few extra nanometres. Compared to a standard EOS R camera, Canon states that the Ra can detect four times the Ha levels – and we can confirm that it performs as promised. As seasoned DSLR users, we know what to expect of winter targets such as Orion from our own equipment and after only an hour's imaging with the Ra we were impressed by the depth and detail from both the Running Man and Orion nebulae. The clever custom white balance allows for daytime photography and while Canon warns that this capability is limited, we were impressed by the Ra's versatility.

@THESHED/PHOTOSTUDIO, CHARLOTTE DANIELS/CHRIS GRIMMER X 3

Mirrorless

This feature offers key advantages over traditional DSLR astrophotography. Not only is it lighter, but mirrorless cameras allow for faster imaging with no delay for 'mirror flip' and reduced vibrations as the shutter fires. When setting up a shot, the smooth imaging style enhanced our routine.

Full-frame

The Canon Ra's 30MP full-frame sensor improves low light performance and image noise (unwanted artefacts) at a high ISO. At 36mm x 24mm it's physically larger than most designated astro-camera and DSLR sensors and offers a wider field of view over APS-C cropped variants. Furthermore, a full-frame sensor offers an improvement in overall image quality and a higher dynamic range.

Live View

The Canon Ra's Live View function is outstanding for many reasons, but not least because of its clarity and sensitivity in low light. We were able to clearly see nebulae and galaxies via Live View without the need to take an image, saving us time when locating and positioning objects in frame.

Magnification

If the Live View wasn't impressive enough, the 30x magnification overhauls focusing precision. We found it easy to locate a star and reduce its circumference to a pinpoint, with no noise disrupting the process. The 180 per cent zoom capability was also useful for inspecting frames afterwards to check tracking accuracy.

FIRST LIGHT

KIT TO ADD

1. Canon RF 15-35mm f/2.8 L IS USM lens

2. Canon RF 24-240mm f/4 -6.3 IS USM lens

3. Canon EF to EOS R adaptor

► If using a telescope, there is an essential setting that allows the shutter to fire when a lens is not attached. This is found in the custom settings menu and is called 'Enable Release Shutter w/o lens'. Without this the Ra won't operate, as it would normally expect to detect a lens. Meanwhile, for camera and lens photography, the new RF camera lenses have electronic focusers rather than mechanical. On the Canon RF 24-240mm f/4-6.3 IS for example, there is no switch for manual focus. However, the RF lenses can be set to manual focus from the main camera settings menu. Canon has added an interesting detail with this, as once in manual mode the 24-240mm displays a distance scale on the Live View screen.

Tried and tested

We put the Ra through its paces on several objects with our William Optics Zenithstar 61 refractor, alongside lenses loaned from Canon – the RF 15-35mm f/2.8 L and RF 24-240mm f4-6.3 IS USM. The Ra's dexterity shone through while we were imaging a Milky Way panorama. Imaging with moderate low-level light pollution at 15mm, the Milky Way's wintertime position was revealed as shallow, but the nebulosity in and around Cygnus was quite visible. Despite the local light pollution we were surprised at how clean and free of noise (unwanted artefacts) our frames remained.

The Ra comes with a new Raw file format – CR3. This might not sound significant, but as astrophotography software is often built by individuals, it alters the process of image stacking. At the time of review, stacking software did not recognise CR3 files, but Adobe Photoshop does and this allowed us to convert CR3 to TIFF before stacking. Due to the detail captured, we discovered the CR3 files are large – our deep-sky sub exposures were between 30MB and 40MB – so you need to ensure your memory card can store a few hours' worth of data. Price wise, the Ra comes in at less than Canon's standard 'R' variant, yet we know it's still a hefty price tag. However, for sheer versatility, ease and pleasure to use, the Ra is well worth the outlay.

VERDICT

Build & design	★★★★½
Connectivity	★★★★½
Features	★★★★½
Features	★★★★★
Imaging quality	★★★★★
OVERALL	★★★★½

Touch-screen sensitivity

When touch-screen imaging is enabled, we were amazed at how lightly we needed to touch the LCD screen to take a shot – a light tap rather than a firm prod. There was no risk of nudging the camera to take an exposure, or while changing ISO and exposure settings.

The Alnitak and Horsehead region of Orion, taken with the Canon Ra camera and RF 24-240mm lens, with 80 x 90" exposures at ISO 2000

A four-pane Milky Way panorama, captured with the Ra and RF 15-35mm lens, with four single 60" exposures, using ISO 1600 at f/2.8

ALL PHOTOS: CHARLOTTE DANIELS/CHRIS GRIMMER

BBC Sky at Night MAGAZINE

LOTS OF WAYS TO ENJOY THE NIGHT SKY...

✦ Television

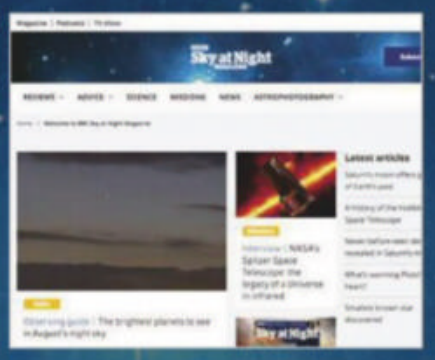
Watch The Sky at Night *TV show each month and get exclusive insight from the presenters*

◀ Back Garden Astronomy Week

Want to discover the night sky but don't know where to start? Sign up to our regular email events for no-nonsense stargazing advice

▲ Social media

Follow on Twitter and Facebook to get essential news and website updates



▲ Online

Visit our website for the latest reviews, observing guides and expert advice

✦ Digital editions

Read each issue on phone or tablet with Android or iOS apps

✦ Special issues

Delve deeper into observing, astrophotography and space exploration with our long reads

▲ Podcasts

Listen in as the magazine team and guests discuss the latest astro news

▲ eNewsletters

Top targets to observe each week, delivered straight to your inbox

Discover more at **www.skyatnightmagazine.com**

FIRST LIGHT

Celestron StarSense Explorer LT 70AZ refractor

An easy-to-use, smartphone app-enabled telescope that punches above its price point

WORDS: PAUL MONEY

VITAL STATS

- **Price** £135
- **Optics** 70mm fully coated objective lens
- **Focal length** 700mm, f/10
- **Mount** Manual altazimuth mount with smooth, altitude slow-motion control
- **App control** StarSense app with StarSense sky recognition technology and planetarium
- **Extras** StarSense dock for your smartphone, 25mm and 10mm eyepieces, 2x Barlow lens, 90° erect image diagonal, StarPointer red dot finderscope
- **Weight** 3.35kg
- **Supplier** David Hinds Ltd
- **Tel** +44 (0)1525 852696
- **www.**dhinds.co.uk

Relatively small telescopes often get a bad press that they don't really deserve; sometimes being put down for having low light grasp and therefore not giving good views of the night sky. My own experience suggests otherwise, having used a 60mm refractor to spot up to 70 of the well-known Messier deep-sky targets when I began my astronomical journey. We need to appreciate that these telescopes won't give a 'Hubble view', and it's with this in mind that we approached the new StarSense Explorer range, with our review taking a look at the first and smallest available, the LT 70AZ.

The LT 70AZ is a refractor with a 70mm diameter front objective lens with fully coated optics and a focal length of 700mm, giving a focal ratio of f/10. The aluminium tube is sturdy, quite lightweight and is mounted on a basic altaz fork mount with a slow-motion control for fine adjustment of the altitude, while general adjustment is made by loosening the thumbscrew. Azimuth adjustment is made via another thumbscrew but there is no fine adjustment. Indeed, we found no need for one, being able to nudge the azimuth to fine tune it. Focusing is by a basic rack and pinion focuser and it can take 1.25-inch format eyepieces and accessories.

The telescope is supplied with two eyepieces, 25mm and 10mm, along with a 2x Barlow lens and an erect image star diagonal. A simple red dot finder and tripod with accessories tray completes the system. However, an unusual and unique difference to the StarSense Explorer system is a strange looking contraption on top of the telescope tube. This is the StarSense Explorer phone dock, which incorporates a smartphone holder and a mirror. It turns a simple, basic manual telescope into one that can easily locate objects via a touchscreen phone and the StarSense app (suitable for Android 7.1.2 and higher, and iPhone 6 upwards). We'll come to this in our box about the StarSense adaptor and mirror holder (see below). ▸

Smartphone app-enabled

Although the StarSense smartphone adaptor and mirror holder give this otherwise normal-looking refractor a rather unusual appearance, it will transform your observing sessions. Simply download the StarSense app from Google Play or the Apple app store and insert your smartphone in the holder. Next, you have to align the smartphone with the telescope when you start up the app. Once this was done we were pleased to discover that it stayed aligned for the sessions in which we used the scope. The smartphone app is the core of the system: it plate solves the view of the sky the phone camera sees reflected in the mirror, allowing it to work out where it is pointing. This enables the planetarium part of the app to show you the way via onscreen arrows to a highlighted or chosen target. Move the telescope manually until you are almost on target, before leaving the scope for it to refine its position. Then you can fine tune the position so that the onscreen indicator box turns green to indicate you are on target. And it works, with all of our targets placed close to the centre of the target box and in the eyepiece too.

@THESHED/PHOTOSTUDIO X 2, CELESTRON X 2

Refractor tube

The optics are housed in an aluminium tube of 812.8mm length with the focuser fully racked out and 690mm with it fully racked in. The tube is 76mm in diameter with a fixed dew shield that prevents the front objective lens from misting up. The whole tube is very lightweight, weighing only 1.63kg.

SCALE

Mount

The mount is a simple altaz design allowing movement up and down and sideways. There is a single slow motion control for fine tuning the altitude via an adjustable rod with rough adjustment done via a simple knob. Motion in azimuth is achieved by loosening the azimuth knob and gently rotating the whole telescope.

Tripod

The black, aluminium tripod is lightweight at 1.72kg and adjustable to a maximum height of 1.32m, giving a good range of adjustment for viewers of all ages. It comes with a simple but effective accessories tray that can take the eyepieces and 2x Barlow lens, keeping them handy for use.

Accessories

Two 1.25-inch fit eyepieces of 25mm and 10mm, giving magnifications of 28x and 70x, are provided along with a 2x Barlow lens that doubles the magnification of each, plus an erect image star diagonal which is useful in an altaz system. A StarPointer red dot finder is also provided, which helps with initial alignment.

FIRST LIGHT

KIT TO ADD

1. Celestron 1.2-inch Moon filter set

2. Celestron LensPen Optics Cleaning Tool

3. Celestron PowerTank Glow 5000

► With our iPhone XR docked and using the StarSense app we were able to locate the brighter targets quite quickly. We took a tour of a wide variety of deep-sky targets, some suggested by the app as a blue circle pointing them out, or via a tour menu of 'Tonight's Best', or a secondary selection of more challenging targets. Relatively bright star clusters such as the Double Cluster, Pleiades, Beehive and the three Messier clusters in Auriga were impressive, with the colourful red giant stars scattered in and among the Double Cluster being especially noticeable. The Orion Nebula was a little low for us but still showed plenty of nebulosity with the 25mm eyepiece, while bumping up the magnification with the 10mm revealed the four stars of the Trapezium Cluster at the heart of the nebula. Indeed, we had good views of the brighter and more well-separated double and multiple, with Castor and Algieba each well split with a 10mm view.

Aiming to please

The view was also rewarding using a 2x Barlow. We tried the multiple star system Iota Cassiopeiae and could split it into two, while at the highest magnification there was a hint of a third companion. Galaxies are in the main much fainter, but we could pick out the five Messier galaxies in the constellation of Leo, M81 and M82 in Ursa Major, while globular clusters such as M3, M62 and M13 were like fluffs of cotton wool. Later in the month we viewed Venus before it approached the Pleiades. It was bright and we found that the combination of the 10mm eyepiece and 2x Barlow lens allowed us to see its almost half phase. On the evening before its closest approach to the Pleiades we were able to frame Venus and the cluster in the view of the 25mm eyepiece.

As long as you don't have high expectations of stunning deep-sky observations, you'll find that the StarSense app turns this manual system into a virtual Go-To system with plenty to explore and enjoy. Overall, we were pleased to discover that the LT 70AZ did a commendable job, providing plenty of pleasing views.

▲ **You can use the StarSense app to locate a target with ease. Some of the brighter targets on view are highlighted with a blue circle (left)**

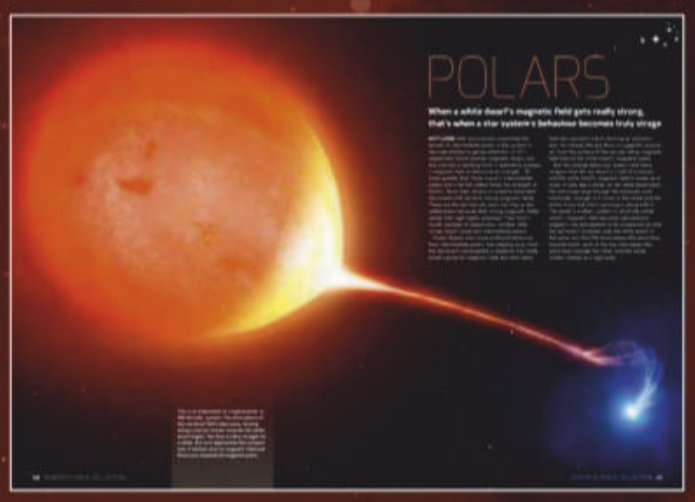
Optics

The front objective of the StarSense LT 70AZ is a 70mm diameter lens with a focal length of 700mm, which gives a focal ratio of f/10. The lens is fully coated to improve light transmission for brighter, crisper views and gathers 100x more light than a human eye.

VERDICT

Build & Design	★★★★★
Assembly	★★★★★
Ease of Use	★★★★★
Features	★★★★½
Optics	★★★★½
OVERALL	★★★★½

SPECIAL EDITION



ONLY £9.99 INC P&P*

FROM THE MAKERS OF BBC Sky at Night MAGAZINE

THE GUIDE TO THE UNIVERSE

The latest special edition from *BBC Sky at Night Magazine*, *The Guide to The Universe* takes you on a journey from the Solar System to the edge of space to encounter the familiar and exotic objects that make up the Universe.

Beautifully illustrated throughout, with expert and clear-cut descriptions, it will give you a new perspective on our place in the vastness of space.

PLUS subscribers to *BBC Sky at Night Magazine* receive FREE UK delivery* on this special edition.

ORDER YOUR COPY TODAY

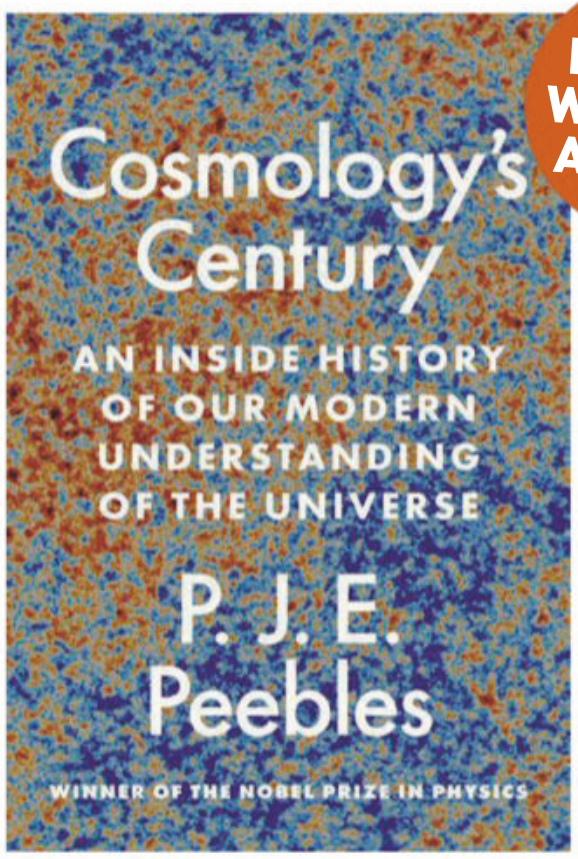
www.buysubscriptions.com/Universe2020

Alternatively call 03330 162138† and quote 'Guide to the Universe Print 1'

† UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8am–6pm and Sat 9am–1pm.

*Subscribers to *BBC Sky at Night Magazine* receive FREE UK POSTAGE on this special edition. Prices including postage are: £11.49 for all UK non-subscribers, £12.99 for Europe and £13.49 for the Rest of World. All orders are subject to availability. Please allow up to 21 days for delivery. Offer ends 30th June 2020

BOOKS



NOBEL-WINNING AUTHOR

Cosmology's Century

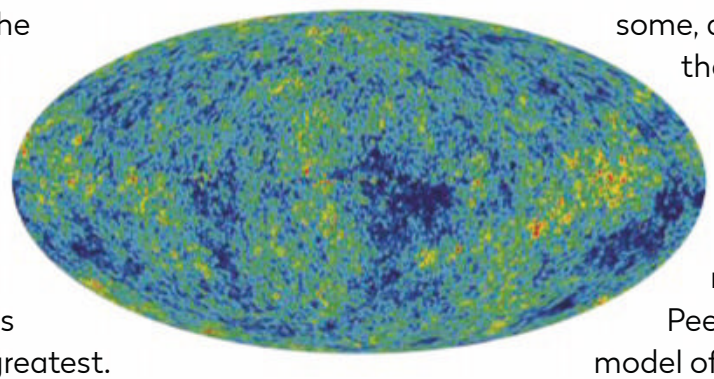
PJE Peebles
Princeton University Press
£30 ● HB

Among astronomy's many achievements in the 20th century, the prediction and discovery of the cosmic microwave background radiation (CMBR) is surely one of the greatest. It not only clinched the case for the Universe's origin in a 'Big Bang' 13.8 billion years ago, but also provided a new means of studying the early cosmos. As a PhD researcher at Princeton in the early 1960s, Jim Peebles was among the team that predicted the CMBR's existence, while his subsequent career focused on developing ideas about the evolution of cosmic structure and the role of mysterious dark matter, for all of which he was awarded the 2019 Nobel Prize in physics.

It's hard then to imagine anyone better placed to recount the inside story of modern cosmology. Unusually among his contemporaries, Peebles has always taken a keen interest in the origins of the ideas with which he wrestles each day, and his latest book is a magisterial summing up of a century of science, from Einstein's 1915 general theory of relativity, to the turn of the millennium and beyond.

Rather than opt for a strictly chronological approach, he tackles his subject through the development of particular ideas and concepts, such as Einstein's principle that the Universe must be homogeneous (uniform) on the largest scale, the various 'fossils' (including the CMBR) that can tell us about the early Universe, and the rival and sometimes complementary models used in modern cosmology. Delving into archives and recalling a lifetime of contacts with other key players, he offers a unique perspective on how some of the mind-bending ideas we now take for granted came about.

The academic structure of numbered sections and subsections, and exhaustive references may be off-putting to some, and of course the use of equations is sometimes unavoidable when discussing the scientific minutiae, but Peebles' text is a model of unshowy clarity throughout, and the gist of his arguments and stories remains easy to follow even if you want to 'skip the math'. For anyone seriously interested in the ways of science and how we came to understand our place in the Universe, this is essential reading. ★★★★★



▲ **Big Bang leftovers? The cosmic microwave background radiation (CMBR)**

NASA

__Giles Sparrow__ is a science writer and a fellow of the Royal Astronomical Society

Interview with the author
PJE Peebles

What is cosmology and when did it begin?

Cosmology is an ancient art. Physical cosmology is the theory and observation of the nature of the physical Universe based on what we know about it on the largest scales we can observe. This line of research traces back to Einstein's thought that a logically constructed Universe is the same everywhere: with no edges. Others soon added the astronomical evidence that this near uniform Universe is uniformly expanding. We now have a theory that passes many demanding tests, which makes a persuasive case that our theory is a useful approximation. The theory is certainly not complete, but then all of physical science is incomplete. That's why we're still employed.

Does it frustrate you that we still don't know what the vast majority of the Universe is made of?

No. There are many things we can be very sure we never will know. For example, what is happening on planets around stars in another galaxy? The human race will never know. I am excited that experiments in progress may actually tell us something more definite about the nature of dark matter. No one promised we can discover that, but we are still learning many things

If there was one cosmological question you could instantly know the answer to, what would it be?

That would be no fun. But I would not complain if I were to be informed of the composition of dark matter.

***PJE Peebles** is a Nobel Prize-winning physicist and Albert Einstein Professor Emeritus of Science at Princeton University*

Extraterrestrials

Wade Roush
MIT Press
£12.99 ● PB

It was in 1950 that Enrico Fermi first theorised that, given the age and size of our Galaxy, the number of stars and planets within it and the odds of intelligent life developing on each planet, the Milky Way should be teeming with extraterrestrials. That being so, he asked: "Where is everybody?"

Wade Roush's *Extraterrestrials* delves into this paradox. We are taken through the history of philosophical speculations about life on other worlds, from the ancient Greeks right up to the scientific surveys, experiments and investigations being made by astronomers and astrobiologists today.

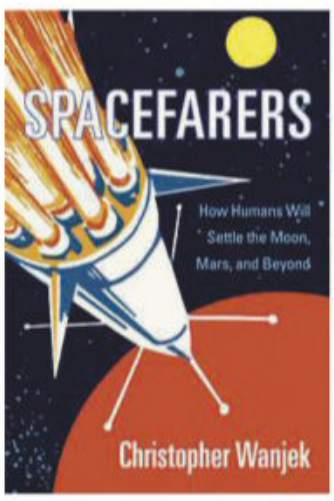
Using the famous Drake equation as a road map, the author guides us through our search for aliens, the birth and evolution of SETI (the Search for Extraterrestrial Intelligence) to scan the skies for signals from alien civilisations and the messages that we have broadcast to reach out to them. He explores the advances in the fields of extremophile and exoplanet research that have extended our ideas of where life could thrive – the ever more varied potential homes for aliens both on moons in our own Solar System and on planets orbiting in habitable zones around distant stars.

All the various solutions to Fermi's paradox are discussed – from the pragmatic to the bizarre – in this clear, concise and engagingly written book. It is a perfect stepping off place for anyone wishing to investigate how far we have come in answering one of the biggest questions in science: are we alone in the Universe? ★★★★★

***Jenny Winder** is a freelance science writer, astronomer and broadcaster*

Spacefarers

Christopher Wanjek
Harvard University Press
£23.95 ● HB



Stephen Hawking called for humans to spread out across space, to guard against disasters threatening our future. Elon Musk is planning private missions to colonise Mars. But what challenges must be faced in making such epic voyages a reality?

Half a century has passed since Apollo astronauts flew to the Moon. After that, it was 'job done' and there was no political appetite to return. Humans have since ventured no further than low-Earth orbit, on space stations such as the ISS.

Wanjek argues that it is the promise of economic rewards, from such activities as mining and tourism, that will drive a new space race to the Moon, asteroids and planets, just as it has driven Earth-bound expeditions throughout history.

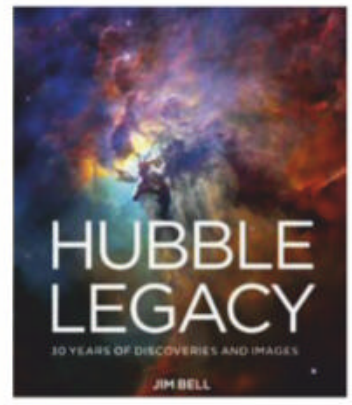
Spacefarers sets out to describe the very real difficulties that must be confronted in order to make our home on new worlds within our Solar System and beyond. Travellers in outer space will swap a warm hospitable Earth for hostile and potentially deadly environments. Wanjek offers a daunting list of perils that will face interplanetary crews, from cosmic and solar radiation poisoning to physical and mental health issues. The closest example of such claustrophobic existence on Earth is aboard a nuclear submarine, where crews may be confined for three months at a time. A journey to Mars might take nine months.

Spacefarers is a fascinating read for anyone interested in the practicalities of living away from Earth, and describes just how engineers, scientists and entrepreneurs are planning to expand humanity's horizons. ★★★★★

***Paul Sutherland** is a space writer and journalist*

Hubble Legacy

Jim Bell
Sterling
£25 ● HB



In *Hubble Legacy*, Jim Bell takes a celebratory tour of the many important contributions the Hubble Space Telescope has made to our understanding of the Universe.

Both the foreword by astronaut and 'Hubble repairman' John M Grunsfeld and the book's first section give a delightfully vivid account of the telescope's history, covering its launch, engineering and the five service missions that have kept it operational for 30 years. Those seeking more technical detail may prefer something like Haynes's *NASA Hubble Space Telescope Owners' Workshop Manual*, but it sets you up for the breathtaking anthology of photography that follows. There is something for everyone to delve into, from distant galaxies to globular star clusters. In the nebula category, you'll find some of Hubble's most famous and ground-breaking images. The real eye-opener is just how much Hubble has taught us about our own backyard – its first ever images of Pluto's surface, for example, helped the New Horizons mission team to plan its flyby observations in 2015.

The print quality diminishes the clarity the images deserve – photography enthusiasts will find better Hubble photography books on the market – but this is perhaps made up for by the comprehensive explanations accompanying each photo.

It concludes with a final look at the future of space observatories, once Hubble is decommissioned this decade. With five new space observatories in various build and concept stages, there is much to look forward to. But as this book demonstrates, they all have a tremendous legacy to live up to.
★★★★☆

***Nisha Beerjeraz-Hoyle** is a space and astronomy writer*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Dust cap with desiccant for 2-inch openings

Price £62 • **Supplier** 365 Astronomy
www.365astronomy.com

Putting your scope away for a while? Help protect your telescope from dust and damp while in storage with this cap. A dessicant (drying agent) pack fits in the cap to soak up any moisture that might harm your optics.

2 Explore Scientific camera dovetail

Price £52.99 • **Supplier** Harrison Telescopes
www.harrisontelescopes.co.uk

Convert your equatorial mount to hold a camera using this special dovetail rail. The 45mm-wide plate comes with 2mm graduations on the side to help you find the perfect point of balance for the camera.

3 The star mug

Price £12 • **Supplier** Science Museum
http://shop.sciencemuseum.org.uk

While on the shelf, this mug shows a starry sky. But fill it up with hot tea or coffee to keep you going through the night and you'll reveal six of the best-known constellations hidden among them.

4 Optolong SII narrowband filter

Price £119.90 • **Supplier** Widescreen Centre
www.widescreen-centre.co.uk

ADVANCED Bring out the red of nebulae with this narrowband filter, which only allows through the light from the SII (Sulphur II) emission line. Use alongside other filters to create a full colour image of the nebulae.

5 Softshell touchscreen gloves

Price £9.99 • **Supplier** Mountain Warehouse
www.mountainwarehouse.com

Keep your hands warm without sacrificing your dexterity with these gloves. A textured finish on the palm and fingers maintains grip, while the lightweight fabric is both wind and shower proof to keep out the elements.

6 Moon playing cards

Price £10.99 • **Supplier** Present Indicative
www.presentindicative.com

Celebrate the Moon while playing your favourite card games with this Moon-themed set of playing cards. Each card features a full colour image of a lunar-related sight from NASA's archives – be it the Eagle lander on its way to the lunar surface or the Moon's face itself.

PULSAR OBSERVATORIES

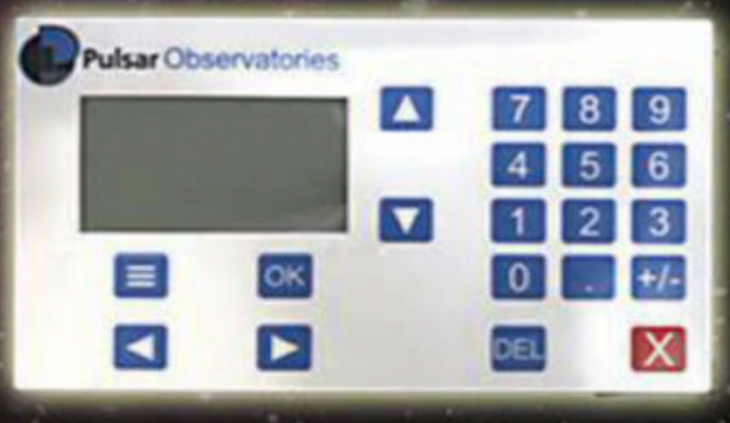
EUROPES LEADING OBSERVATORY DOMES

A Pulsar Observatory Dome is not just somewhere to store your equipment. It has many benefits that will allow you to take your home astronomy to the next level!

ADVANTAGES OF A PULSAR DOME:

- Observe in comfort
- Eliminates annoying stray light
- Protection from wind chill
- Less cooling down time
- Full automation potential
- Excellent dark adaption
- Virtually maintenance free
- Highest Quality GRP construction
- Simple home assembly
- Long life durability of GRP
- Installation service available

PRICES START FROM JUST £2595.00



Our Industry leading drive system makes full automation of your observatory dome easier than ever before!

CHECK OUT OUR WEBSITE FOR DRIVE OPTIONS AND DOME ACCESSORIES INCLUDING ANTI-VIBRATION PIERS AND PIER ADAPTER PLATES

www.pulsarobservatories.com

sales@pulsar-observatories.com

Tel: 01366 315006

Jane Green interviews Dr Beth Healey

Q&A WITH AN ISOLATION RESEARCHER

Researchers spend months cut off from the world to investigate the effects of isolation on astronauts. How can this help us to deal with social distancing?

Where did you spend your year cut off from the rest of the world?
Concordia is one of three permanent all-year research facilities in Antarctica. Jointly operated by scientists from France and Italy, it also hosts European Space Agency (ESA) scientists and is located 3km above sea level on the Antarctic Plateau. I spent 14 months with a crew of 12: a 50/50 mix of scientists and technical teams of different nationalities and backgrounds. This included an isolated nine-month period over winter when we studied with ESA.

▲ **Remote working: the Concordia research facility is situated 1,200km inland in Antarctica. It is completely isolated during the long winter months**

What research were you conducting?
I am a medical doctor but my main role for ESA was psychological and physiological research. The base is situated at a high altitude, equivalent to 4,000m at the equator, with very thin air. We measured the crew's blood levels to understand how lack of oxygen affects behaviour. We also studied stress indicators.

The crew's sleep and wake cycle was monitored to focus on how isolation affects sleep patterns, especially during the long polar night. We tested risk-taking behaviour, memory testing and more. The results are being used to introduce countermeasures that target predictable behavioural changes throughout long-duration missions.

What was it like living in extreme isolation?
After I returned from Antarctica, friends asked if I had been lonely. Actually, it was claustrophobic; we couldn't get away from each other and I found that quite exhausting. Privacy was an issue, so our living quarters were sacrosanct.

It was remote. I felt a constant low-level stress, because if something went wrong during the polar winter there was no rescue. I became acutely aware of my mortality.

Sensory deprivation was a risk factor, causing mood changes and depression. There was little colour, smells or sounds and I missed mud on my shoes. The lack of animal and plant life was a disadvantage for everyone. I remember when I first arrived, the chef spotted a stowaway slug on a lettuce leaf – this became his 'pet'!

Dr Beth Healey is a medical doctor who spent a year working for ESA at Concordia in Antarctica, researching the effects of isolation

Were there benefits to isolated living?
It gave me an opportunity to step off life's treadmill. Everything was less rushed so I became more 'present'. I was able to understand the effect of my behaviour on others in a confined space, and I learnt to recognise how their behaviour affected me. If I was upset, my normal response would have been to hibernate and not talk about it, but that would not work at Concordia.

How did you pass the time?
It taught me how important it is to keep busy. I had my work, but I also read, exercised and did yoga.

It was also important to keep in touch with home. We had an old-fashioned dial-up internet connection which was often pretty slow, but we communicated with family and friends to avoid homesickness. Although this was vital, I became aware that sometimes this could be seen as excluding other team members. We made sure we dined together and also organised Italian and French-themed nights; anything to provide structure and promote team spirit.

What tips would you give to people self-isolating?
Maintain your own personal routine, whatever it is, especially your sleep/wake cycle, as disruption will induce biological change and mood swings. Plan ahead for future trips so you have a focus when normality resumes. Also, read more and learn something new.

It's important to exercise outside if you can. When inside, keep your private space, however small, and establish boundaries. Have others respect your space and likewise respect theirs. Don't sweat the small things either; focusing on minor issues can lead to pettiness. Slow down, as there is no rush and you will see and hear so much more.

Keep communicating with friends and family outside the home, but don't exclude those around you. Make an effort to be present; dine together; talk more; keep a calendar of things to do and look forward to doing them. Vitally, satisfy that intrinsic human need to connect with nature, by caring for animals, doing gardening, keeping plants and growing seeds.

Telescope House

Telescope Specialists Since 1785

Web: www.telescopehouse.com
Email: sales@telescopehouse.com
Tel: 01342 837098

Sign Up

16MP - £842
1.7MP - £1256
7.1MP - £2099

Introducing the three new Explore Scientific Deep Sky Cameras - all simple to use One Shot Colour systems featuring 1.7, 7.1 and 16 Megapixel Sensors. These cameras all feature set-point cooling and come with control software and heavy duty storage & carry cases.

Explore Scientifc 99% Reflectivity Diagonal - £142

Explore Scientific iEXOS-100 Wifi Mount £349

Explore Scientifc 127mm FCD100 Carbon Fibre Apo - £2287

EXPLORE SCIENTIFIC

Explore Scientifc Maksutov Newtonian - £892

165mm & 152mm + Losmandy G11 PMC8 Mount Megadeals

Telescope House are pleased to bring you these two unique deals buy the extraordinary Explore Scientific 165mm or 152mm Apo Triplets together with the advanced Explore Scientific Losmandy G11 PMC8 Wireless Control Mount and make massive savings.

Get organised with the Explore Scientifc Eyepiece & Accessory Bag- £25

Introducing the Explore Scientifc 52-Degree Eyepiece Waterproof LER range From £59.99

Bresser Astrophoto Tracking Mount From £265

The Bresser Astrophoto Tracking Mount is designed to be used with DSLRs and small telescopes for long duration astrophotography, providing a tracking platform to counteract the Earth's rotation and create wonderful wide field shots of the skies above us.

Available in head only and wedge tripod configurations.

Explore Scientific Sun Catcher Solar Filters From £18

HOT PRODUCT 2015 SKY

Lunt LS50 - From £1183

Excellent pressure-tuned portable Solar Scope

Lunt LS60 - From £1880

Explore Scientific Solarix Solar Film Filter £18

Excellent Value 100% Safe Solar Film. Ideal for DIY!

Lunt LS80/B1800 - £5214

ZWO ASIAIR Pro Wireless Scope control, Autoguiding & more. Arriving soon!

Find the full range of ZWO Cameras at Telescope House From £151

Bresser Full HD USB Camera/ Eyepiece £50

Lunt LS100/ B1200 - £6478

Website: www.telescopehouse.com
Email: sales@telescopehouse.com | For sales and advice call: 01342 837098

All prices correct at time of press. Subject to change. Errors and omissions excepted.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

See Mercury in the evening sky and catch sight of Serpens – the only constellation divided in two

When to use this chart

1 June at 24:00 AEDT (13:00 UT)
15 June at 23:00 AEDT (12:00 UT)
30 June at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JUNE HIGHLIGHTS

June is a great time to observe Mercury in the evening sky. It opens the month close to a maximum elongation (angular distance) from the Sun with a size of 7.6 arcseconds and a phase similar to a first quarter Moon. Mercury loses altitude and grows in angular size as it approaches inferior conjunction (between Earth and the Sun) at month's end. On the 22nd, still 5° above the horizon as twilight ends, its diameter has reached 11.5" and it shows a thin crescent (around a two-day old Moon).

STARS AND CONSTELLATIONS

The constellation of Ophiuchus is represented by an asterism of faint stars, 'the coffin', framing a dark area of the Milky Way caused by obscuring galactic dust. He is depicted as holding a snake curved around his waist. This is Serpens, the only constellation divided in two – Serpens Caput for the head and Serpens Cauda for the tail. Ophiuchus was seen as the god of medicine by the Greeks, with unequalled powers. The snake taught him to raise the dead by using a magical herb.

THE PLANETS

During the evening twilight, Mercury is the only planet visible, but this inner speedy world will disappear into the solar glow towards the month's close. The action switches to the eastern sky with Jupiter, followed closely by Saturn, rising in the early evening (20:00) – transiting mid-morning. About midnight, Mars and Neptune arrive to be followed by Uranus at 04:00 mid-month. June sees Venus return to the morning sky and it's up before dawn as the month closes.

DEEP-SKY OBJECTS

This month's trip is to Lupus, sitting high in the evening sky between the Pointers (Alpha (α) and Beta (β) Centauri) and Libra. Xi (ξ) Lupi (RA 15hr 56.9m, dec. -33° 58') is a bright double star. Its near-white components are mag.+5.3 and mag. +5.8, separated by 10.4".

Approximately 3° west of Xi Lupi is a fine example of a dark nebula called Barnard 228. This dust cloud is best viewed through wide-angle instruments (even large binoculars) to see its blackness contrasted against the surrounding bright Milky Way star field. Overall, the nebula is around 3° long, approximately 0.3° wide and orientated in a SE to NW direction. It runs roughly parallel to Psi¹ and Psi² Lupi around 0.6° westward. This wide pair of mag. +4.6 stars offer a good colour contrast, white and yellow respectively, separated by 0.7°.

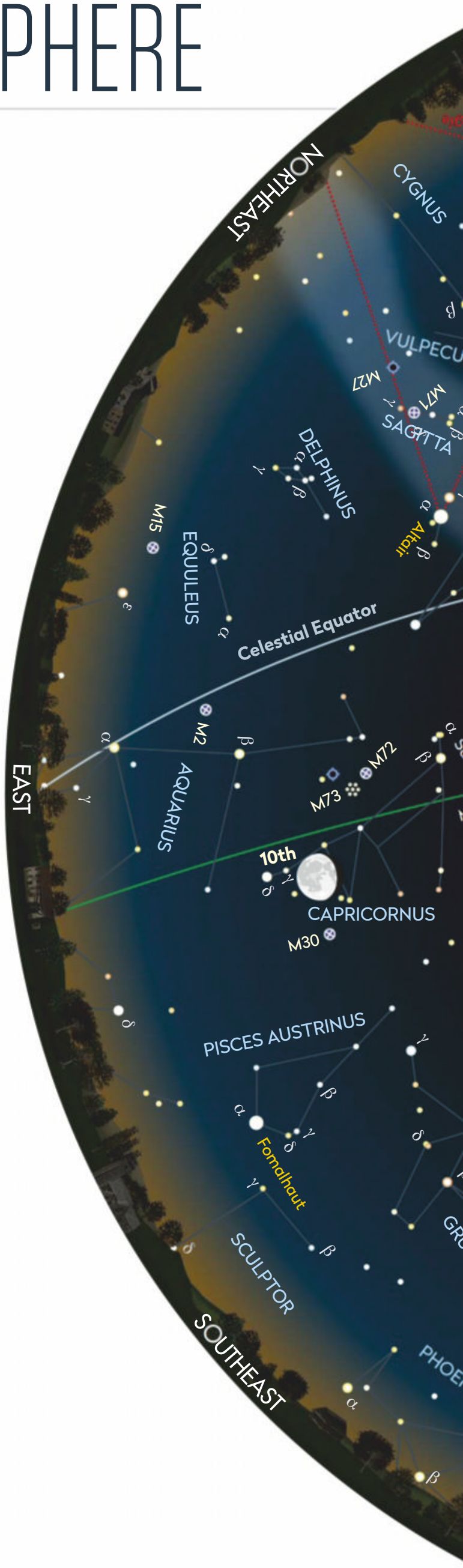


Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Vega
LYRA
M57
Albireo
HERCULES
M92
Keystone
M13
CORONA BOREALIS
BOÖTES
Kite
M3
COMA BERENICES
Arcturus
M53
Rasalgethi
Rasalhague
Coffin
OPHIUCHUS
SERPENS CAPUT
M5
AQUILA
SERPENS CAUDA
M10
M14
M12
M107
M100
M60
M58
M87
M86
Realm of Galaxies
LEO
VIRGO
M61
1st
28th
SCUTUM
M11
M16
M17
M18
M23
M9
4th
Antares
M4
M20
7th
M8
M6
M7
Jupiter
Saturn
M75
SAGITTARIUS
Teapot
Ecliptic
LIBRA
Spica
M104
CORVUS
Barnard 228
SCORPIUS
Fish Hook
M83
M68
CRATER
CORONA AUSTRALIS
TELESCOPIUM
ARA
NORMA
Rigel Kent
LUPUS
Omega Centauri
NGC 4945
HYDRA
Peacock Star
INDUS
CIRCINUS
Hadar
CENTAURUS
TRIANGULUM AUSTRALE
Jewel Box
Coalsack
CRUX
MUSCA
ANTLIA
PAVO
APUS
OCTANS
CHAMAELEON
TUCANA
47 Tucanae
South Celestial Pole
VELA
SMC
MENSA
HYDRUS
VOLANS
LMC
Achernar
RETICULUM
DORADO
PICTOR
CARINA